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ENVIRONMENTAL STATEMENT

for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
OFFICE OF SPACE SCIENCE
LAUNCH VEHICLE AND PROPULSION PROGRAMS

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SUMMARY

(X) Draft ( ) Final

Responsible Federal Agency: National Aeronautics and Space Administration (NASA), Office of Space Science, Launch Vehicle and Propulsion Programs

1. (X) Administrative Action ( ) Legislative Action

2. NASA OSS Launch Vehicle and Propulsion Programs is responsible for the launch of approximately 20 automated science and applications spacecraft per year. These launches are for NASA programs and those of other U. S. government agencies, private organizations, such as the Comsat Corporation, foreign countries, and international organizations. Launches occur from Cape Kennedy, Florida; Vandenberg Air Force Base, California; Wallops Island, Virginia; and the San Marco Platform in the Indian Ocean off Kenya.

3. Spacecraft launched by this program contribute in a variety of ways to the control of and betterment of the environment (e.g., meteorological satellites). Environmental effects caused by the launch vehicles are limited in extent, duration, and intensity and are considered insignificant.

4. There are no short-term alternatives to the current family of launch vehicles. The possiblities for changes in the family, including new stage and launch vehicle developments, are continuously reviewed. A new booster (first stage) with liquid hydrogen and liquid oxygen propellants, as used in the Centaur upper stage, would produce a more innocuous product of combustion (water). Such a development might cost as much as $500 million and take as long as 5 years. The space shuttle, intended to replace most of the current family of launch vehicles, is expected to be operational about 1978-1980.

5. Comments requested from:

   CEQ, EPA, OMB, AEC
   DOD
   Department of State
   Department of Commerce
   Department of Transportation
   Department of Interior.

6. Draft Statement published August 1, 1972.

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PROGRAM DESCRIPTION

The NASA Office of Space Science (OSS) Launch Vehicle and Propulsion Programs provides launch vehicles and launch vehicle operations for automated space missions of OSS, the NASA Office of Applications (OA), the NASA Office of Aeronautics and Space Technology (OAST), other government organizations (e.g., NOAA, DOD, and AEC), commercial firms (e.g., Comsat Corporation), foreign governments, and international organizations. This responsibility is met by a number of on-going launch vehicle programs and appropriate vehicle and propulsion system research and development activities which support current and expected future requirements.

The current and near future family of launch vehicles and a brief description of the significant features of each is given in Table 1.

In the period 1968-1971 (including all launches planned in 1971), these vehicles were launched at a collective average rate of about 20 per year, of which an average of 10 per year were launches of OSSA* payloads. Current projections indicate an average launch rate of 19 per year for the period 1972-1974.and it is expected that a similar launch rate will prevail in the 1975-1980 period. By 1980 it is expected that the space shuttle will be operational, and it will replace most of the launch vehicles covered here.

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* Office of Space Science and Applications. This office was divided into OSS and OA in late CY 1971.

TABLE 1. CURRENT AND NEAR FUTURE LAUNCH VEHICLES USED FOR NASA AUTOMATED MISSIONS[1,2]*

Vehicle	Vehicle Status	Type of Propellant	Quantity of Propellant[a]** (kg)	Total Vehicle Weight (kg)	Thrust Levels at Zero Altitude (Newtons)	Maximum Diameter (m)	Length[b] (m)	Launch Site(s)
Scout	Operational			17,960	439,110	2.7 (including fins)	22.6	Wallops Island, WTR, San Marco
Stage 1[c]		AP/Al/PU	9,687					
Stage 2		AP/Al/PBAA	3,769					
Stage 3		AP/Al/NC/NG	1,175					
Stage 4		AP/Al/PBAN	276					
Stage 5		AP/Al/NC/NG	86.6 (Stage 5 is optional and is not included in the overall vehicle parameters.)					
Delta(3 Castor)	Operational			90,630	1,298,670	4.6	28.0	ETR, WTR
Augmentation		AP/Al/PBAA	11,250					
Thor[d]		LOX/RJ-1	66,230					
DSV-3E-3[e]		IRFNA/UDMH	4,853					
TE-364-3[f]		AP/Al/CTPB	658					
Delta(6 Castor)	Operational			104,200	1,801,440	4.6	28.0	ETR, WTR
Augmentation [Other stages same as Delta(3 Castor)]		AP/Al/PBAA	22,500					
Delta(9 Castor)	Operational			117,800	1,801,440	4.6	28.0	ETR, ETR
Augmentation [Other stages same as above]		AP/Al/PBAA	33,750					
Atlas/Centaur	Operational			146,100	1,823,290	4.9	35.7	ETR
SLV3D		LOX/RP-1	121,600					
Centaur		LOX/LH_2	13,650					
Titan IIIE/Centaur	In Development			634,100	9,876,340	10.1	48.5	ETR
Zero Stage		AP/Al/PBAA/AN	394,600					
Core I		N_2O_4/Aerozine 50	116,100					
Core II		N_2O_4/Aerozine 50	30,160					
Centaur		LOX/LH_2	13,650					
Titan IIIC	Operational			629,100	9,876,340	10.1	38.4	ETR
Zero Stage		AP/Al/PBAA/AN	394,600					
Core I		N_2O_4/Aerozine 50	116,100					
Core II		N_2O_4/Aerozine 50	30,160					
Transtage		N_2O_4/Aerozine 50	10,610					

* Numbers in parentheses are references. See Appendix A.

** Notes on next page.

Note: To convert to pounds, multiply kilograms by 2.20
To convert to pounds force, multiply Newtons by 0.225
To convert to feet, multiply meters by 3.28

TABLE 1. CURRENT AND NEAR FUTURE LAUNCH VEHICLES USED FOR NASA AUTOMATED MISSIONS(1,2)

(a) Expended weight, including miscellaneous fluids and gases, TVC fluid, ablatives, etc., in addition to propellant. See note below for nomenclature.

(b) Length varies with the payload shroud and may be greater than shown for some configurations.

(c) A somewhat larger first stage (Algol III) of similar characteristics is being developed with a propellant loading of 12,690 kg.

(d) An improvement program is underway which will increase the Thor propellant to 79,020 kg.

(e) An improved configuration is being developed which will use 4,690 kg of N_2O_4/Aerozine 50 propellant.

(f) An uprated version of the TE-364-3 (the TE-364-4) is being developed. The propellant will be increased to approximately 1,043 kg, The FW-4 is also used as an upper stage replacing the TE-364. Its propellant load is 276 kg.

NOTE: The following notation has been used for propellants:

AP	=	ammonium perchlorate
Al	=	aluminum
PU	=	polyurethane
PBAA	=	polybutadiene-acrylic acid
NC	=	nitrocellulose
NG	=	nitroglycerine
PBAN	=	polybutadiene-acrylic acid-acrylonitrile
LOX	=	liquid oxygen
RJ-1	=	a kerosene type hydrocarbon
IRFNA	=	red fuming nitric acid inhibited with HF
UDMH	=	unsymmetrical dimethyl hydrazine
CTPB	=	carboxy terminated polybutadiene
RP-1	=	a kerosene type hydrocarbon
LH_2	=	liquid hydrogen
AN	=	acrylonitrile
Aerozine 50	=	equal parts of hydrazine and unsymmetrical dimethyl hydrazine

TOTAL IMPACT OF THE PROGRAM

The potential environmental impact of the National Aeronautics and Space Administration, Office of Space Science, Launch Vehicle and Propulsion Programs activities is summarized in Table 2. No significant impact is expected from normal current and planned future activities. The possible effects of certain types of accidents or flight failures involving Titan vehicles may be of marginal significance. However, the combinations of events leading to such situations are believed to be very rare: no examples have occurred.

In terms of global or even national significance, the contributions of NASA launch vehicles for automated missions to environmental pollution appear to be many orders of magnitude below those of other sources of such pollution.

Conversely, the space science and applications spacecraft launched by these vehicles have made significant contributions to the understanding, prediction, and use of the environment, and, thus, ultimately to its betterment. Future activities are expected to contribute even more to human welfare as the applications areas are further developed.

The commitment of resources to this program is modest and is not of major significance to the national economy. The program is not a major consumer of any scarce or limited resource.

Development activities currently include an improved second stage for the Delta vehicle, development of an uprated Thor booster, development of an uprated TE-364 motor (the TE-364-4), development of a new Scout first stage (the Algol III), integration of the Titan IIIE/Centaur vehicle, and improvements of the Centaur stage. Additionally, certain research and development activities are carried out through the Supporting Research and Technology (SR&T) program, such as technology development of a large (2,670 Newton thrust) hydrazine monopropellant engine.

Vehicles are launched from four sites: Wallops Island (Scout), Kennedy Space Center (Delta, Atlas/Centaur, Titan IIIE/Centaur, and Titan IIIC), Vandenberg Air Force Base (Scout and Delta), and San Marco Platform (Scout).* The individual vehicle projects are managed by the Lewis Research Center (Atlas/Centaur, Titan IIIE/Centaur), Goddard Space Flight Center (Delta), and Langley Research Center (Scout). Titan IIIC is managed by the Space and Missile Systems Office of the United States Air Force.

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* See Appendix C for site maps.

TABLE 2. SUMMARY OF ENVIRONMENTAL IMPACT OF NASA OSS LAUNCH VEHICLE AND PROPULSION PROGRAMS

Area of Concern	Type of Event or Activity: Normal Launch	Accident or Abort	Development and Test
Air Quality	Effects limited to the immediate vicinity of the launch pad.	Limited area within facility boundaries possibly subjected to HCl concentrations above public exposure criteria in event of an on-pad fire or low-level abort of Titan IIIE/Centaur or Titan IIIC. No significant effect for other vehicles.*	No significant effect
Water Quality	No significant effect	Limited ocean volume (about 0.02 cubic miles) possibly subjected to hydrazine and UDMH concentrations above the maximum allowable concentations as a result of unlikely combinations of failures for Titan IIIE/Centaur and Titan IIIC. No significant effects for other vehicles.*	No significant effect
Noise	No significant effect	No significant effect	No significant effect
Reentry Debris	No significant effect	No significant effect	No significant effect
Environmental Enhancement	Space Science and Applications Spacecraft make positive contributions		
Commitment of Resources	No significant commitment of scarce or limited resources.	No significant commitment of scarce or limited resources.	No significant commitment of scarce or limited resources.

i.e., Scout, Delta, and Atlas/Centaur

ACTIVITIES WHICH MAY RESULT IN ENVIRONMENTAL IMPACT

The activities which result from the operation of NASA OSS Launch Vehicle and Propulsion Programs are as follows:

- Advanced Studies
- Research and Development
- Launch Vehicle Manufacture
- Launch Vehicle and Component Testing
- Launches of Automated Spacecraft.

Possible environmental effects which might result from these activities include:

- Air Quality
- Water Quality
- Noise
- Reentry of Launch Vehicle Debris
- Population Shifts (Due to manpower needs for the programs)
- Solid Waste
- Pesticides.

The major activities are concentrated in, but not restricted to, Southern California and Florida.

Of the above possible environmental effects, the first four are considered to be of greatest potential significance and will be considered in greater detail in subsequent sections of this Environmental Statement. No population shifts of significance are expected to result from current or planned future activities. The solid waste generated by these activities is generally of relatively high value and is usually recovered. Use of pesticides is at most only incidental to the manufacture, test and launch of space vehicles. Consequently, population shifts, solid wastes and pesticides will not be considered further.

The advanced studies, most research and development activities, manufacturing, and most testing, are relatively clean and quiet operations and do not directly produce significant environmental effects. However, such activities do consume power, steel, aluminum, paper, etc., and thus, may have some secondary impact on the environment. This secondary impact is difficult to quantify, but probably does not grossly differ from that resulting from the employment of an equal number of people in other activities. Consequently, it will not be considered further.

Some research and development activities and testing, particularly those related to rocket propulsion systems, result in the handling and consumption of propellants and, thus, may affect air and water quality and generate noise. At the present time, acceptance testing of production liquid propellant rocket engines is the major consumer of propellants in these areas of activity. Propellant consumption in current research and development activities is minor. The impact of these activities is considered in the subsequent sections of this statement.

The actual launch and flight of launch vehicles is the major activity which may cause some temporary perturbation in the environment. In addition to normal vehicle flight, the effect of possible abnormal flight conditions will be considered in the following sections. It should be noted that the preparations for all launches include an extensive safety analysis for both normal and possible abnormal events. The vehicle trajectory, flight sequence, launch date and time, and other parameters are adjusted, as necessary, to meet safety requirements. Examples of trajectory plots and corresponding impact points for all launch vehicles considered in this Environmental Statement are shown in Appendix B.

AIR QUALITY

Source and Nature of Emissions

All current and near future launch vehicles are powered by chemical rocket engines. These engines operate by the combustion of a fuel and self-contained oxidizer. The types of fuels and oxidizers are listed in Table 1. The products of combustion exhausted from the rocket nozzle may include compounds and molecular fragments which are not stable at amibent conditions, or which may react with the ambient atmosphere. Knowledge of the detailed composition of rocket exhaust gases is largely based on thermochemical calculations which assume that the propellants are completely mixed in the combustion chamber.

The substances emitted by rocket engines may be derived from the nominal propellant, from additives to the propellant, from impurities in the propellant, or from the engine itself (e.g., ablative components). Major chemical species emitted by rocket engines are:

Water

Carbon Dioxide

Carbon Monoxide

Hydrogen Chloride

Nitrogen

Hydrogen

Aluminum Oxide.

Of the major constituents, carbon monoxide and hydrogen chloride are generally recognized as air pollutants and may present a toxicity hazard. In the upper atmosphere, water and carbon dioxide may be considered as potential pollutants due to their low natural concentration, and their possible influence on the Earth's heat balance and on the ozone and electron concentration.*

In a normal launch, the exhaust products are distributed along the vehicle trajectory. Due to the acceleration of the vehicle, and the staging process, the quantities emitted per unit length of trajectory are greatest at ground level and decrease continuously. In the event of a vehicle failure in flight, the vehicle destruct system ruptures the propellant tanks and releases all remaining propellants. These will normally ignite and burn; however, only limited information is available concerning the products formed or the extent to which the propellants are consumed.

In the period 1965 through May, 1971, approximately 90 percent of the NASA automated vehicle launches have been successful, and only 3 failures (out of 138 launches) have been on-pad or at relatively low altitudes where significant quantities of propellant remained in the vehicle.

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* NASA is currently conducting investigations on the effects of combustion products on the upper atmosphere. These investigations are being coordinated with the DOT and NOAA.(3)

In addition to the emissions during launch, all liquid propellant rocket engines used in these launch vehicles are subjected to an acceptance firing at the manufacturer's facilities. The quantity of propellant consumed in these tests is in the range of 1/4 to twice the propellant consumed in flight, typically about 1/3. Also, research and developmental activities result in the consumption of propellants other than in flight. At the present time, research and development activities associated with OSS Launch Vehicle and Propulsion Programs result in the consumption of significantly less propellants than does acceptance firing.

Impact on the Environment

Potential air pollutants from NASA OSS Launch Vehicle and Propulsion Programs activities may arise from the following situations. The pollutant involved is also indicated.

Situation	Pollutant
Engine Test	Combustion Products
Launch	Combustion Products
On-pad Accident	Propellants, Combustion Products
In-flight Abort	Propellants, Combustion Products.

Table 3 lists the combustion products and propellants of primary concern, together with some reported and estimated human exposure criteria.

TABLE 3. EXPOSURE CRITERIA FOR SOME COMBUSTION PRODUCTS AND PROPELLANTS

Substance	Controlled Populations[a] TLV,[c] ppm	Controlled Populations[a] Short-Term Emergency Limits[5], ppm 10 min.	30 min.	1 hr.	Uncontrolled Populations[b] Exposure from Ordinary Operations, ppm 10 min.	30 min.	1 hr.	Uncontrolled Populations[b] Emergency Exposure, ppm 10 min.	30 min.	1 hr.
HCl	5	30	20	10	4[d]	2[d]	2[d]	7[d]	3[d]	3[d]
CO	50			200			30[e]		--	125[8]
Al_2O_3 (mg/M^3)	15	50[9]	25[9]			--			--	
NO_2 (N_2O_4)	5	30	20	10	1[f]	1[f]	1[f]	5[f]	3[f]	2[f]
Hydrazine	1	30	20	10	1[g]				--	
UDMH	0.5	100	50	30	0.5[g]				--	
$AlCl_3$ (mg/M^3)	10[h]		--			--			--	

(a) Controlled populations consist of persons with known medical histories, subject to periodic health checks, and generally under the control of the responsible agency. Such persons are normally employees with jobs that will potentially result in exposure to known contaminants.

(b) Uncontrolled populations consist of persons with unknown medical histories, not subject to periodic health checks, and not generally controlled by the responsible agency. The general public is included in this classification.

(c) No short duration exposure criteria for controlled populations appear applicable for ordinary launch operations. Threshold Limit Values (TLV) are time-weighted concentrations for 7 or 8 hour work days and a 40-hour work week, except that the values for HCl and NO_2 are also considered ceiling values not to be exceeded.[4] TLV's are thought to be conservative for short duration exposures of controlled populations for relatively infrequent normal operations.

(d) While there are no criteria for short-term exposure of uncontrolled populations to HCL which have official standing, the values quoted here have been proposed by a responsible organization after careful study of the problem (See Reference 6).

(e) Based on 1.5% Carboxyhemoglobin in 1 hour exposure. See Reference 7.

(f) There are no officially accepted criteria for short-term exposure of uncontrolled populations to nitrogen oxides. The criteria given here have been proposed by a responsible organization after careful study. (See Reference 10).

(g) Arbitrarily set equal to the 8 hour industrial TLV: i.e., 1/48 of the acceptable industrial dose.

(h) Based on hydrolysis to HCl. In subsequent discussion, $AlCl_3$ is considered only in terms of its contribution to overall HCl levels.

Table 4 briefly describes dispersion characteristics within selected atmospheric layers. Table 5 lists the combustion products of concern emitted into these layers. Note that quantities of CO_2 and H_2O are tabulated for the higher altitudes, due to the concern that these materials may have an influence on the Earth's heat balance or on the ozone or electron concentrations at high altitudes.

Normal Launch

Ground Level Effects. Ground level concentrations of the pollutants resulting from space vehicle launches have been estimated using a multilayer atmospheric diffusion model and assuming a buoyant rise of the exhaust cloud. (This model is somewhat similar to the multilayer model developed by GCA Corporation[14,15], but is based on the point source model described in Reference 16.) Figures 1 and 2 present the results of these calculations for the combustion products CO and HCl covering three atmospheric stability criteria (slightly unstable, neutral, and slightly stable), and three heights of inversion layers (500, 1000, and 2000 meters).* The bands labled "Deltas" include within them the Delta(3 Castor), Delta(6 Castor), and Delta(9 Castor). The exposure criteria shown on Figures 1 and 2 are the industrial TLV's for controlled populations (considered conservative for short duration, infrequent exposures) and the criteria for exposure from ordinary operations for controlled populations (See Table 3).

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* Figures 1 and 2 indicated that the predicted concentrations of pollutants are relatively sensitive to the meteorological conditions. The predicted concentrations in the region within a few kilometers of the launch pad are even more sensitive to the assumed initial distribution of pollutants, particularly the initial quantity of pollutant assumed to be located within a few meters of ground level. Further work, including experimental measurements under known meteorological conditions, is required if more refined estimates are desired.

TABLE 4. DISPERSION CHARACTERISTICS WITHIN SELECTED ATMOSPHERIC LAYERS*

Atmospheric Layer; Altitude Range	Temperature Structure	Wind Structure	Characteristic Mixing Rate
Below nocturnal inversion 0-500 m	Increase with height	Very light or calm	Very Poor
Below subsidence inversion 0-1500 m	Decrease with height to inversion base	Variable	Generally fair to inversion base
Troposphere 0.5-20 km	Decrease with height	Variable; increase with height	Generally very good
Stratosphere 20-67 km	Isothermal or increase with height	Tends to vary seasonally	Poor to fair
Mesosphere-Thermosphere Above 67 km	Decrease with height	Varies seasonally	Good

* Adapted from References (11) and (12).

Note: To convert to feet, multiply meters by 3.28

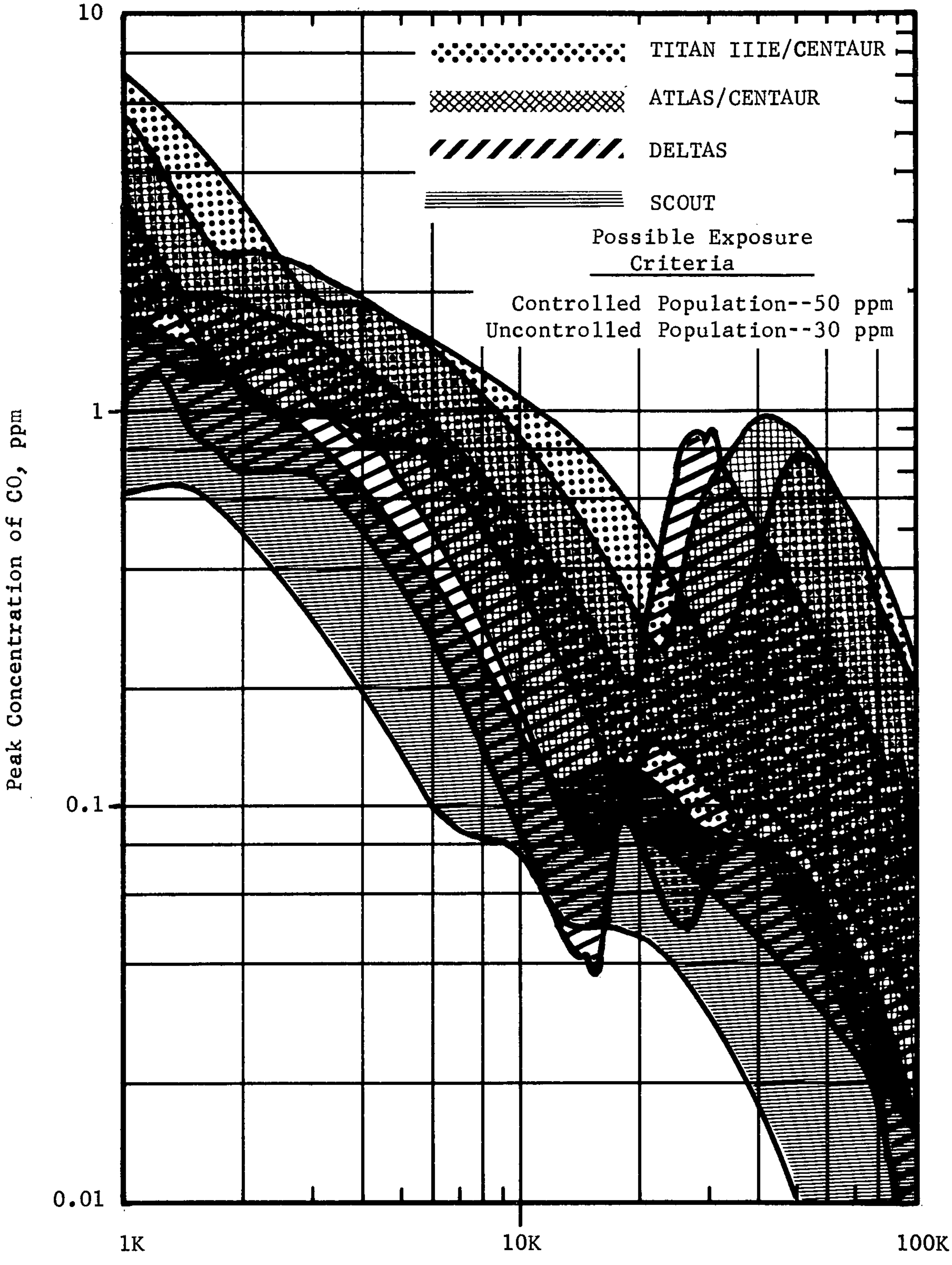
TABLE 5. QUANTITIES OF POTENTIAL POLLUTANTS EMITTED INTO SELECTED ATMOSPHERIC LAYERS

Note: To convert to pounds, multiply kilograms by 2.20

Atmospheric Layer	Nocturnal Inversion			Subsidence Inversion			Troposphere			Stratosphere					Mesosphere-Thermosphere				
Altitude Range	0-500 m			0-1500 m			0.5-20 km			20-67 km					Above 67 km				
	Emission, kg																		
Vehicle	HCl	CO	NO*	HCl	CO	NO*	HCl	CO	NO*	HCl	CO	NO*	CO_2	H_2O	HCl	CO	NO*	CO_2	H_2O
Scout	60	110	nil	180	310	0.5	2,290	~~10,780~~ 4090	6.4	760	970	2.3	100	340	450	830	1.4	64	198
Delta(3C)	690	2,600	1.8	1,130	4,120	3.2	1,710	10,790	4.5	0	14,400	0	10,700	9,300	0	3,360	70	3,970	2,990
Delta(6C)	830	2,500	2.3	1,840	4,260	5.0	3,920	11,320	11	0	14,900	0	11,100	9,700	0	4,930	70	3,650	3,270
Delta(9C)	1,100	3,020	3.2	1,750	4,550	4.5	5,630	13,740	15	410	13,350	0.9	9,600	8,400	0	5,830	70	4,340	3,800
Atlas/Centaur	0	6,310	0	0	10,030	0	0	24,310	0	0	17,500	0	13,100	11,400	0	4,540	0	3,380	15,760
TIIIE/Centaur**	9,800	17,510	30	14,920	26,540	41	47,170	83,000	126	24,040	43,320	750	19,700	18,800	0	3,060	1,530	20,400	47,450

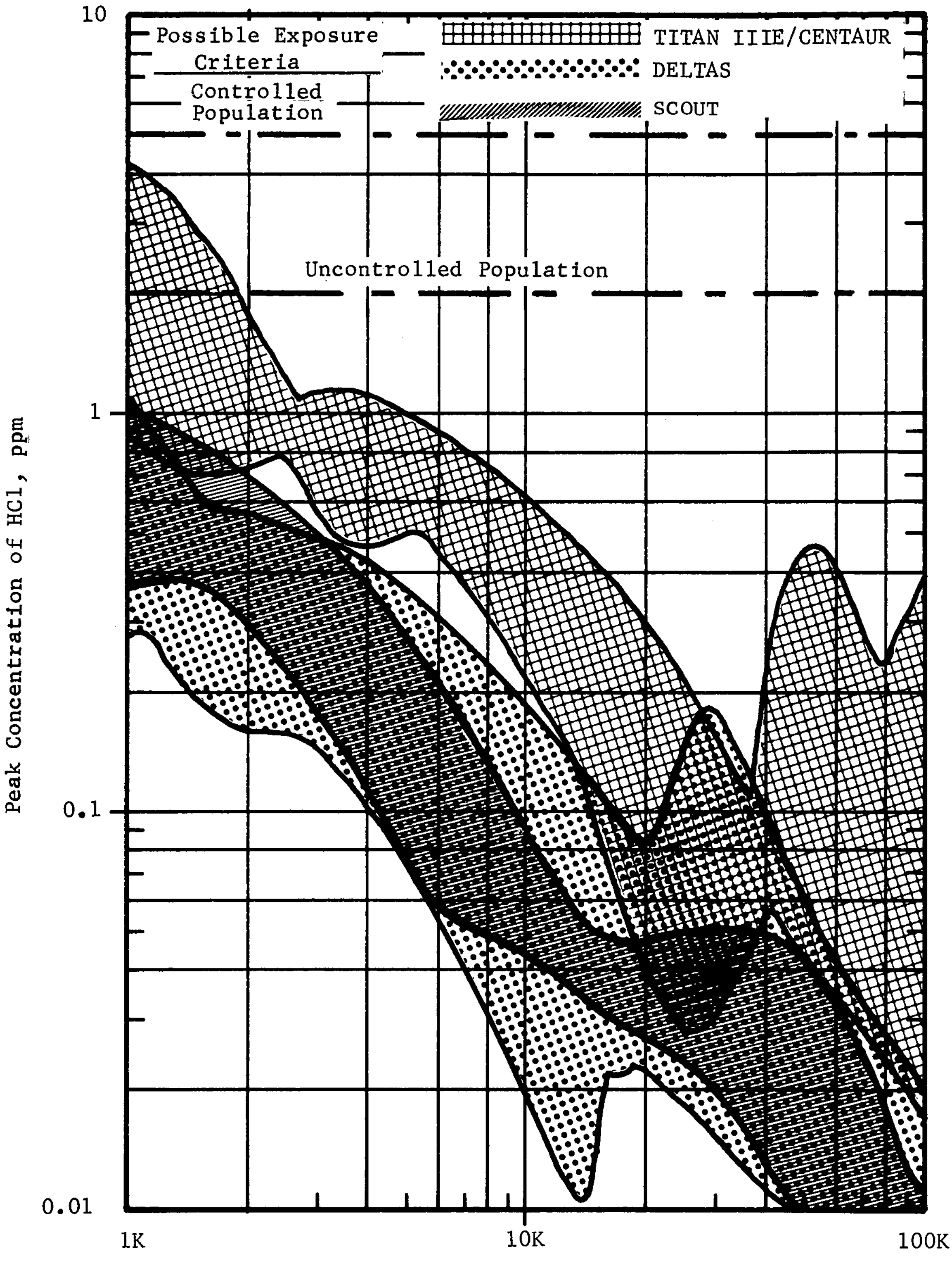
* The NO formed from N_2 impurity in the stages using liquid oxygen (Atlas, Thor, Centaur) is not included. The concentration of NO in the exhaust of such stages has been estimated at 3 ppm for an N_2 impurity level of 600 ppm.(13) The resulting NO emissions are negligible.

** The Titan IIIC is equivalent to the TIIIE/Centaur except for changes in the emissions above 67 km. These changes are not significant in terms of upper atmosphere effects.



Note: To convert to miles, multiply meters by 6.2×10^{-4}

FIGURE 1. ESTIMATED PEAK CO CONCENTRATIONS DOWNWIND OF LAUNCHES. BANDS FOR EACH VEHICLE INCLUDE RESULTS FROM ANALYSIS FOR THREE ATMOSPHERIC STABILITY CRITERIA AND THREE INVERSION HEIGHTS



Note: To convert to miles, multiply meters by 6.2×10^{-4}

FIGURE 2. ESTIMATED PEAK HCl CONCENTRATIONS DOWNWIND OF LAUNCHES. BANDS FOR EACH VEHICLE INCLUDE RESULTS FROM ANALYSIS FOR THREE ATMOSPHERIC STABILITY CRITERIA AND THREE INVERSION HEIGHTS

It should be noted that the distance scales on Figures 1 and 2 are the maximum distances at which the stated concentrations would be expected.* Lines of constant concentration enclose an approximately elliptical area with the major axis equal to the plotted downwind distances.

Emissions into the upper troposphere are rapidly diluted by turbulent mixing and wind shear in that layer. No local or global ground level concentrations of significance will result. Emissions into the upper stratosphere, the mesosphere and the thermosphere will not result in detectable ground level concentrations.

The foregoing figures and table indicate that HCl emissions from the Titan vehicles present the only environmental hazard of significance. This hazard is modest, and even under unfavorable meteorological conditions is estimated to be confined to controlled areas.

Estimates have also been made of the concentrations of nitrogen oxides resulting from these launches. At a distance of 1 km, a maximum concentration of 0.38 ppm was estimated for a Titan IIIE/Centaur launch. This is more than an order of magnitude below the suggested exposure criteria for controlled personnel. Uncontrolled personnel would be subjected to negligible exposure.

<u>Upper Atmospheric Effects</u>.

Water. In the stratospheric layer, the vehicles emitting the largest amount of water are the Titan IIIE/Centaur and the Titan IIIC. An estimate of the spread of the exhaust cloud that would be required before the H_2O concentration fell to the ambient value as given in the U. S. Standard Atmosphere was made. At 25 km altitude,

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* A table of minimum distances from the vehicle launch pads to press sites, facility boundaries, and the nearest communities is located in Appendix C.

the effects of the cloud would blend into the ambient background by the time it had expanded to one square kilometer. At 60 km altitude the cloud would have to expand to about 800 square kilometers to reach an equilibrium with ambient H_2O concentrations.

The quantity of rocket exhaust which would double the concentration of H_2O, CO_2, and NO in the atmosphere above 105 km has been calculated.(17) Results from a comparison of such calculations with actual emissions above 67 km are as follows:

Total Rocket Exhaust Required to Double the Natural Concentration above 105 km (kg)			Actual Total Annual Exhaust Emissions above 67 km Resulting from NASA Launches of Automated Missions (1969-1971 Average) (kg)
H_2O	CO_2	NO	
5.9×10^8	1.3×10^{10}	5.9×10^{10}	1.4×10^5

The effect of water vapor (or any other exhaust emission as will be shown subsequently) from a launch vehicle upon the ozone concentration can be considered as negligible from the small area covered by the exhaust cloud. The rocket can create a small hole in the ozone layer but the photochemical processes taking place in the atmosphere will quickly fill up any void of ozone.

The potential effect of H_2O on the Earth's heat balance is discussed, together with the effect of CO_2, in the next section.

Carbon Dioxide. Estimates of the area in the stratosphere into which the Titan IIID* cloud would have to expand before the carbon dioxide density would reach that of the ambient air were made as in the case of water vapor. For CO_2 at 25 km the cloud must expand to less than 0.1 km^2 before the CO_2 would reach ambient levels. At 60 km the cloud would drop below ambient levels of CO_2 concentration after it expanded to an area of 4 km^2.

* Lower stages for the Titan IIIE/Centaur and Titan IIIC.

The principal concern regarding large increases of CO_2 and H_2O in the upper atmosphere and above it are the effects these constituents would have on the global radiation balance, through absorption or scattering of incoming or outgoing radiation. The above estimates of the area required for diffusion of H_2O and CO_2 to background levels indicate that emissions of these compounds will have negligible effects.

Nitrogen Oxides. Calculations of natural NO levels in the layers above 60 km have been made which predict concentrations of about 10^{-2} ppm.[18]

The NO emitted from the exhaust of the Titan IIIE and Titan IIIC dissipates below the 10^{-2} ppm concentration when the exhaust cloud expands beyond 4.5 km^2 at 25 km and beyond 600 km^2 at 60 km.

It is reasonable to suppose that NO levels above the natural equilibrium level will be reduced through dissociation by solar ultraviolet radiation until the natural equilibrium is again restored.

Hydrogen Chloride. Hydrogen chloride emissions could have an effect on the ionization level in the upper atmosphere. If this change in ioniziation level is to have an effect on radio wave transmission (the only effect known to be of importance), the emission of HCl in layers above approximately 90 km (the nominal base of the E layer of the ionosphere) would have to be significant. Only the Scout has HCl emissions that would affect the E layer or the D layer below it. The 449 kilograms of HCl per flight emitted by the Scout above 67 km is minimal. Calculations of the effect of firing a TE364-3 motor within the F region, emitting 220 kg HCl, indicate that the global electron density would be reduced by a maximum of 0.028%. The natural ionization in the F region regularly fluctuates by a factor of about 10.[19]

In summary, there is no significant effect of the launch vehicles used by NASA for automated missions on the upper atmosphere. Current activities appear to be many orders of magnitude below those which would be expected to product detectable changes in the upper atmosphere.

Engine Tests

Engine tests differ from launches in that all of the propellant used is consumed at ground level. However, the high temperature of the exhaust gases causes them to rise in a buoyant plume. The downwind concentrations of the exhaust gases are dependent on the height of this buoyant rise, and any elevation contributed by the persistence of the exhaust jet.

Ground tests of the Atlas booster engine are probably the critical case for the vehicles considered here. Using the method suggested by Reference 20, a buoyant rise of 487 meters was calculated. Using this as a source height, peak downwind concentrations were estimated by the methods of Reference 16. The maximum downwind concentration of CO predicted was 5 ppm, well within suggested exposure limits.

Tests of the Thor engine would produce essentially the same results. Tests of other engines used by the subject vehicles would have smaller effects due either to the smaller engine sizes or due to the lower concentrations of pollutants in the exhaust.

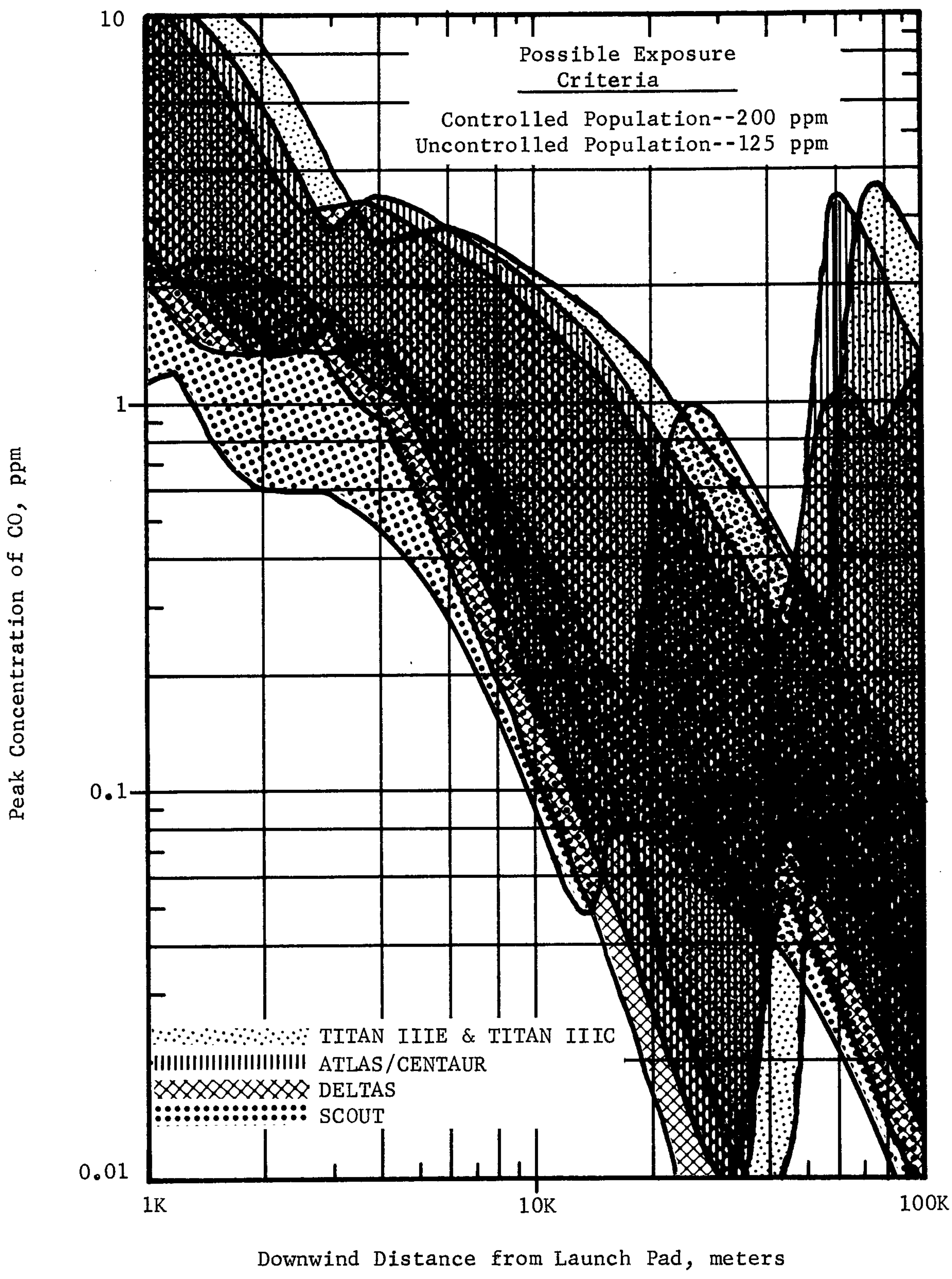
Engine acceptance tests are performed at relatively remote sites, and access to the sites is controlled. Suitable precautions are taken to insure the safety of the test crew, including remote operation and protective equipment.

Abnormal Launches and Accidents

On-pad accidents, either a cold spill of liquid propellant (no fire) or an on-pad fire involving solid propellant motors, and early in-flight failures resulting in abort may produce significant ground level concentrations of toxic materials.

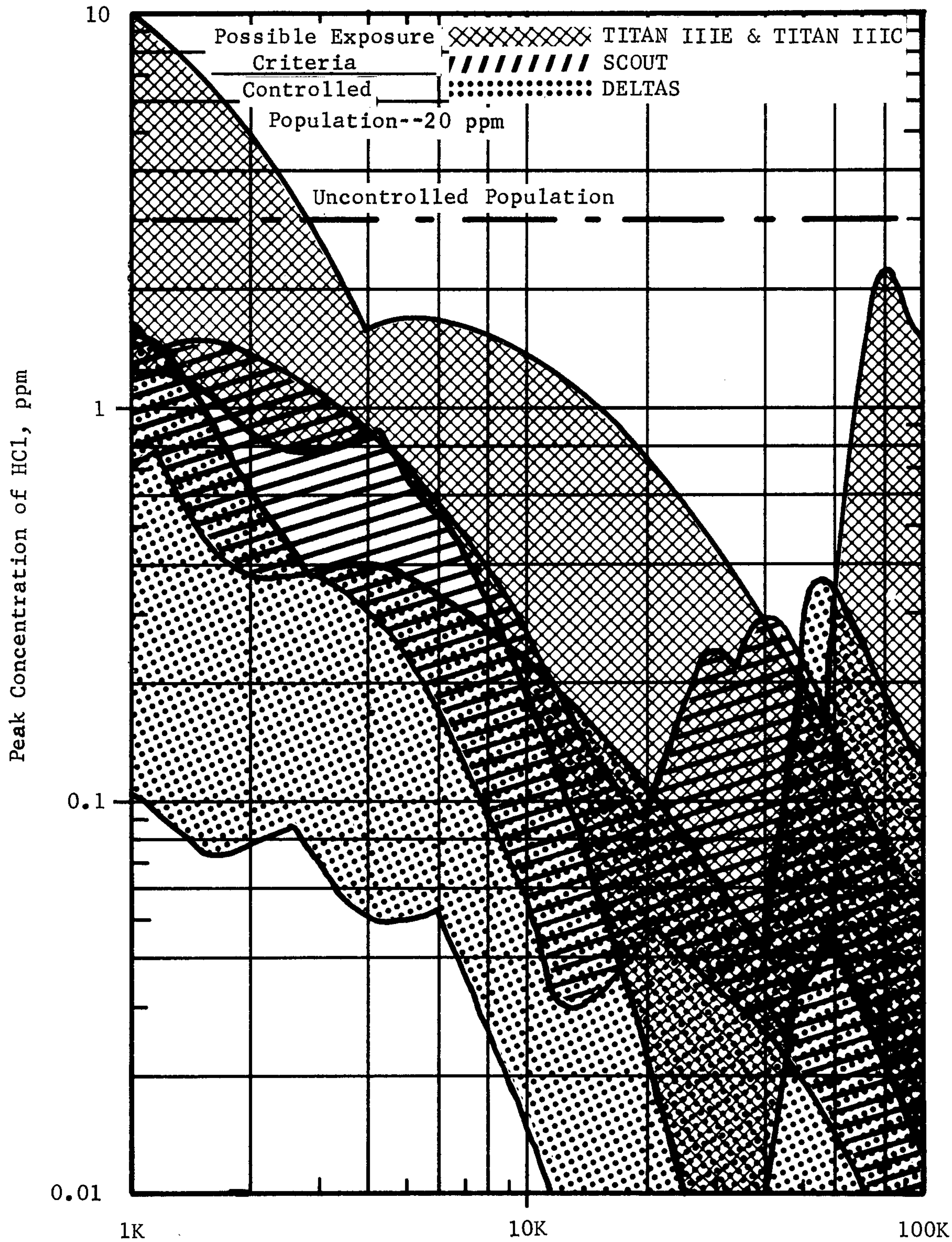
In cold spills, nitrogen tetroxide is the propellant of most concern: the volatility of Aerozine-50 is sufficiently low that a serious hazard is not created by spills. Such events have been analyzed for the Titan IIID and Titan IIIC[21], which represent worst cases for the launch vehicles considered here. Under ordinary meteorological conditions the concentration of N_2O_4 downwind of the spill will fall below the public emergency exposure criteria of 2 ppm within 3 km: under adverse conditions, such concentrations may persist to distances of 6 km. Only controlled areas would be involved in either case. Spills of toxic propellants from other NASA vehicles considered here would have smaller effects due to the smaller propellant quantities involved.

Calculations of the effect of an on-pad fire involving the vehicles of concern here using the buoyant rise, multilayer dispersion model described previously are summarized in Figures 3 and 4. Low level aborts involving complete burning of the propellant should produce results similar to those for on-pad fires.



Note: To convert to miles, multiply meters by 6.2×10^{-4}

FIGURE 3. ESTIMATED PEAK CO CONCENTRATIONS DOWNWIND OF ON-PAD ABORTS. BANDS FOR EACH VEHICLE INCLUDE RESULTS FROM ANALYSIS FOR THREE ATMOSPHERIC STABILITY CRITERIA AND THREE INVERSION HEIGHTS



Downwind Distance from Launch Pad, meters

Note: To convert to miles, multiply meters by 6.2×10^{-4}

FIGURE 4. ESTIMATED PEAK HCl CONCENTRATIONS DOWNWIND OF ON-PAD ABORTS. BANDS FOR EACH VEHICLE INCLUDE RESULTS FROM ANALYSIS FOR THREE ATMOSPHERIC STABILITY CRITERIA AND THREE INVERSION HEIGHTS

Summarizing, accidents or abnormal launches of the vehicles considered here are not expected to cause air pollutant concentrations exceeding the exposure criteria except in the immediate vicinity of the launch pad where access is carefully controlled. Table 6 gives the maximum radius at which specific ground level effects would be anticipated for both normal and abnormal launches. No other effects of significance, either in the lower or upper atmosphere, are expected.

TABLE 6. SUMMARY OF ESTIMATED MAXIMUM RADIUS OF GROUND LEVEL EFFECTS FOR TITAN IIIE/CENTAUR OR TITAN IIIC

Event	Maximum Radius at which Exposure Exceeds Criteria	Limiting Pollutant	Criteria Used*	Meteorological Conditions
Normal Launch	2km	HCl	2ppm	2000m Inversion, Slight Instability
Cold Spill	6km	N_2O_4	2ppm	200m Inversion, low wind speed, night
On-pad Fire	3km	HCl	3ppm	500m Inversion, Slight Instability
Low Level Destruct	3km	HCl	3ppm	500m Inversion, Slight Instability
Engine Test	Criteria Not Exceeded	CO	30ppm	Neutral Stability

* For uncontrolled populations. Normal launch and engine test assume criteria for normal operations. Emergency criteria used for accidental exposures. See Table 3.

WATER QUALITY

Source and Nature of Pollutants

NASA OSS Launch Vehicle and Propulsion Programs may contribute potential pollutants to bodies of water in the following ways:

- On-pad accidents and propellant spills which may result in run-off of propellants to local drainage systems.
- In-flight failures which may result in vehicle hardware and, possibly, propellants falling into the ocean.
- Normal flight, which results in the impact of spent, suborbital stages (containing some residual propellants) and jettisoned hardware into the ocean.
- Eventual reentry of spent stages which have achieved orbit.

The problem of reentry debris is treated separately in this statement. Provisions are made for containing on-pad spills and disposing of the spilled propellant without contaminating the water (or air) environment. On-pad vehicle failures would normally be expected to result in a fire that consumed most or all of the propellants, and, thus, have been handled as an air pollution problem. Any unconsumed propellant would be treated in the same way as a spill. In the period of 1965 through May, 1971, out of 138 launches, one launch* resulted in an on-pad catastrophic failure.

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* Atlas/Centaur Number 5.

In the event of an in-flight failure, the vehicle destruct system ruptures the propellant tanks.* The propellants then ignite and burn, but the possibility exists that a fraction of the propellants, in addition to vehicle hardware, may reach the surface of the ocean. This possibility is treated, together with normal stage impact. Approximately 90% of NASA space launches for automated missions have been successful. Of the 138 launches mentioned above, two launches resulted in failures during the early phase** of flight when significant quantities of propellant remained unused.

Spent vehicle stages which do not achieve orbital velocity are placed on trajectories which result in an ocean impact. In addition to stage hardware, small quantities of propellants (residuals and reserves) impact with the stage. These propellants are released and dispersed into the environment. Their probable effect on the environment has been estimated.

Vehicle hardware will normally sink in the ocean and slowly corrode; however, isolated occurrences of floating hardware have been reported. In major part, such hardware consists of aluminum, steel, and fiber reinforced plastics. A large number of compounds and elements are used in launch vehicles in small amounts; for example, lead in soldered electrical connections and cadmium from cadmium plated steel

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* When the Range Safety Official determines that the vehicle will impact within the safe impact area, he may elect not to destroy the vehicle. This option appears to be exercised most commonly during late stages of the flight when little propellant remains in the vehicle.

** The Delta 59 booster broke up at 103 seconds of flight time, with approximately one-half its propellants remaining. The second stage was subsequently destroyed, releasing all its propellants. The Nimbus B Thor-Agena went out of control and was destroyed with about one-half of the booster propellant and all the second-stage propellant on board. Also, an additional launch had a much later failure; after hydraulic failure of the Delta 73 booster, it was necessary to destroy the second stage after 261 seconds of burn, releasing slightly less than one-half of the second-stage propellants.

fittings. Neither the stage hardware or its corrosion products are believed to represent a significant water pollution problem, as will be discussed in subsequent paragraphs.

Possibilities of water pollution are primarily associated with toxic materials which may be released to and are soluble in the water environment. Rocket propellants are the dominant source of such materials. A secondary consideration relates to oils and other hydrocarbon materials which may be essentially immiscible with water but, if released, may float on the surface of the water, inhibiting oxygen transfer, coating feathers of sea fowl and fouling gills of fish which may come into contact with it.

The toxicity hazard has received attention and Table 7 shows the estimated maximum allowable concentrations (MAC) for the chemical species of concern. Later discussion will confirm that other materials released should pose no threat to plant and animal life. The values in Table 9 are estimates for trout and are probably not much different for many fish species. Threshold Limit Values in air for man are shown for comparison. Critical materials are hydrazine, unsymmetrical dimethyl hydrazine, and their mixtures (Aerozine 50, i.e., A-50).

In contrast, little applicable information exists regarding the "floating oil" problem. However, the maximum physical area and time of persistence can be estimated so that some relative judgement of the environmental impact can be made.

TABLE 7. MAXIMUM ALLOWABLE CONCENTRATIONS (MAC) IN WATER FOR FISH AND IN AIR FOR MAN

Chemical Species	TLV* for Man, ppm (air)	MAC for Fish, mg/l (water)	Comments
Hydrazine (N_2H_4)	1.0[4]	0.7[22]	MAC for fish is the experimental value for trout which lost equilibrium after a 24 hr exposure.
Unsymmetrical Dimethyl Hydrazine [$(CH_3)_2N\text{-}NH_2$]	0.5[4]	0.35	MAC for fish based on ratio of TLV's for hydrazine and UDMH for man.
Aerozine 50 (A-50)	----	0.53	Based on the sum of the toxic effects of hydrazine and UDMH.
Nitrogen Tetroxide	5[4]	95	MAC for fish estimated from the value for nitric acid. Nitric acid is a weaker oxidant and has a MAC value for fish of 100 mg/l[22].
Ammonium Perchlorate (NH_4ClO_4)	----	9100	MAC for fish computed from the threshold of toxicity of sodium chlorate (considering oxidizing properties only)[22].
RP-1 and RJ-1	----	40[22]	MAC for fish only when dispersed. Selected from values on trout exposed to gasoline contamination in water.

* Threshold Limit Value

Impact on the Environment

Potential sources of pollutants to the marine environment and the major pollutants are:

Hardware	-	Heavy metal ions and miscellaneous compounds
Solid Propellants	-	Ammonium perchlorate
Liquid Propellants	-	UDMH, A-50, N_2O_4, RP-1, RJ-1.

Jettisoned or reentered hardware will corrode and, thus, contribute various metal ions to the environment. The rate of corrosion is slow in comparison with the mixing and dilution rate expected in a marine environment, and, hence, toxic concentrations of metal ions will not be produced. The miscellaneous materials (e.g., battery electrolyte, hydraulic fluid) are present in such small quantities that, at worst, only extremely localized and temporary effects would be expected.

The ammonium perchlorate in solid propellants is mixed in a rubbery binder and will thus dissolve slowly. Toxic concentrations would be expected only in the immediate (within a few meters) vicinity of the propellant if they occur at all. As noted in Table 7, the toxicity is relatively low.

The release of liquid propellants into the marine environment poses the greatest potential threat to the environment, particularly in the case of hydrazine based fuels (see Table 7). Thus, those vehicles employing such fuels (Delta, Titan IIIE/Centaur and Titan IIIC) pose the most serious problem.

A-50, UDMH, nitrogen tetroxide and IRFNA are soluble in water, whereas the hydrocarbon fuels, RP-1 and RJ-1 are relatively insoluble.* Thus, the latter two materials are less hazardous to marine life. However, the hydrocarbons have a measurable toxicity when dispersed and retained in suspension in sea water. Liquid oxygen (LOX) and liquid hydrogen (LH_2) pose no toxic threat.

Estimates have been made of the ocean area subjected to toxicant concentrations greater than the MAC for various assumed normal and abnormal vehicle flights. Only those vehicles employing the N_2O_4/A-50 propellant system (Delta** and Titan) were considered. The potential hazard would be less in intensity and relate to a smaller area for all other vehicles.

Tables 8 and 9 show the amounts of propellant remaining in the vehicles at various points along the trajectories, the propellants potentially available for release to the environment at that point in normal flight or following an abort, and the downrange location of the corresponding impact point. The quantities in Tables 8 and 9 were estimated using flow rate and trajectory data.[1] Example trajectory plots and corresponding impact points are shown for all subject launch vehicles in Appendix B.

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* A solubility of between 50 and 100 ppm by weight might be expected for hydrocarbons such as RP-1 and RJ-1. Data concerning the solubilities of hydrocarbons in water are scarce, but a value of 72 ppm for decane at 25C has been quoted.[23]

** All Delta configurations are equivalent in terms of the N_2O_4/A-50 content.

TABLE 8. PROPELLANT QUANTITIES FOR THE TITAN IIIE/CENTAUR

Time from Launch (sec)		Stage: Zero (Solid)	Core I (N_2O_4/A-50)	Core II (N_2O_4/A-50)	Centaur (LOX/LH_2)
0	Propellant remaining, kg	384,610	119,870	27,320	13,670
	Propellant Released, kg				
	Normal	None	None	None	None
	Accident	384,610	119,870	27,320	13,670
	Location*	Near Launch Pad	Near Launch Pad	Near Launch Pad	Near Launch Pad
40	Propellant remaining, kg	221,000	119,870	27,320	13,670
	Propellant Released, kg				
	Normal	None	None	None	None
	Abort	221,000	119,870	27,320	13,670
	Location*	11	11	11	11
123	Propellant remaining, kg		111,430	27,320	13,670
	Propellant Released, kg				
	Normal		None	None	None
	Abort		111,430	27,320	13,670
	Location*		324	324	324
280	Propellant remaining, kg		696 (Residual)	27,320	13,670
	Propellant Released, kg				
	Normal		696	None	None
	Abort		696	27,320	13,670
	Location*		1,908	1,908	1,908
466.4	Propellant remaining, kg			230 (Residual)	13,670
	Propellant Released, kg				
	Normal			230	None
	Abort			230	13,670
	Location*			5,189	5,189
585	Propellant remaining, kg				10,790
	Propellant Released, kg				
	Normal				None
	Abort				10,790
	Location*				9,582

* Downrange location of impact point, km.

Note: To convert to pounds, multiply kilograms by 2.20
To convert to nautical miles, multiply kilometers by 0.54

TABLE 9. PROPELLANT QUANTITIES FOR THE TAT(3C)/DELTA

Time from Launch (sec)		Stage: Castors (Solid)	Stage: Thor (LOX/RJ-1)	Stage: Delta TSE (N_2O_4/A-50)
0	Propellant remaining, kg	11,250	66,230	4,670
	Propellant Released, kg			
	Normal	None	None	None
	Accident	11,250	66,230	4,670
	Location*	Near Launch Pad	Near Launch Pad	Near Launch Pad
15.0	Propellant remaining, kg	7,490	61,680	4,670
	Propellant Released, kg			
	Normal	None	None	None
	Abort	7,490	61,680	4,670
	Location*	Near Launch Pad	Near Launch Pad	Near Launch Pad
38.6	Propellant remaining, kg	None	54,300	4,670
	Propellant Released, kg			
	Normal	None	None	None
	Abort	None	54,300	4,670
	Location*	7.7	7.7	7.7
221	Propellant remaining, kg		137 (Residual RJ-1 only)	4,670
	Propellant Released, kg			
	Normal		137	None
	Abort		137	4,670
	Location*		1,984	1,984
415	Propellant remaining, kg			1,910
	Propellant Released, kg			
	Normal			None
	Abort			1,910
	Location*			3,830

* Downrange location of impact point, km.

Note: To convert to pounds, multiply kilograms by 2.20
To convert to nautical miles, multiply kilometers by 0.54

Characteristics of the Oceans Near the Launch Sites*

The oceans near all the launch facilities are areas of moderate water activity, being neither stagnant nor exceptionally stormy. Major ocean currents run relatively close to all the sites. The three ranges located in the U. S. are in active biological areas and have sport as well as commercial fisheries nearby. Further downrange, the spent stages impact in the open ocean where residual fuel would be of minor significance and quickly dispersed by wave action.

The Eastern Test Range (ETR) is located on the east coast of Florida where the Gulf Stream/Florida Current passes between the Bahama Islands and the mainland at relatively high velocity (up to 1.8 m/sec) during the entire year. The current's influence prevents the typical near-shore green ocean development normally expected for such relatively shallow water. The continental shelf is wide in this area, encompassing the Bahama Islands and extending at least 370 km before dropping off into the Hatteras Abyssal Plain. The area is characterized as a sub-tropical ocean with an associated moderate level of biological activity typified by a large variety of plant and animal species widely dispersed over the area.

The Western Test Range (WTR) is physically near the edge of the continental shelf in an area of relatively strong currents which vary seasonally. Since most NASA launches from WTR are into polar or near polar orbits, the launch vehicles pass southward over the continental shelf (Santa Barbara Channel). The area is a region of very high

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* Discussion based on materials in References 24 through 28.

biological activity influenced by nutrient up-welling along the continental shelf and the seasonally shifting California Current and subsiding counter-currents. The water is cool, permitting a high rate of carbon dioxide fixation characteristic of oceans at higher latitudes.

Wallops Island, Virginia, near the Maryland border, has a temperate climate and moderate water and biological activity. No strong currents pass close to shore and the continental shelf is relatively close to shore. Scout is the only space vehicle launched from this site.

The San Marco Scout Launch Facility is located in Formosa Bay on the coast of Kenya near the equator. The climate and ocean are tropical. The continental shelf in this area is very narrow and the Somali Current system, which shifts with the seasons, passes some distance out to sea. The level of operations involves only an occasional Scout launch.

Normal Launch

A normal launch and flight will result in the downrange impact of spent stages containing small quantities of residual propellants. Estimates of the maximum radius at which the MAC will occur were made for the Titan Core I stage (worst case). Estimates were based on symmetric diffusion into a semi-infinite ocean[(29)] and diffusion limited to a depth of 3 m[(30], corresponding to a case where the vertical diffusion coefficient is much smaller than the horizontal diffusion coefficient.

Chemical Species	Maximum Radius at which the MAC Occurs, meters	
	Symmetric Diffusion	Depth Limited to 3 m
N_2O_4 (MAC = 95 mg/l)	8.5	12.2
A-50 (UDMH + Hydrazine) (MAC = 0.53 mg/l)	45.1	132.6

The affected volume is insignificant.

The RP-1 and RJ-1 residuals in the Atlas and Thor stages will result in a non-persistent surface film covering less than 280 square m[31,32] and, thus, do not pose a serious hazard to the environment.

Aborted Flights

In the event of an in-flight failure in the early stages of flight, the vehicle destruct system ruptures the propellant tanks and disperses the propellants into the air. The propellants then normally ignite and burn. It is possible that some fraction of the propellant may reach the ocean surface. If the destruct system should fail to operate, the vehicle might impact intact and release the entire quantity of remaining propellant into the ocean. As noted previously, the probability of an abort during the early stages of flight appears to be in the order of 1%.

One case is known in which a vehicle destruct system has failed to operate when called upon.*[33] Assuming this failure rate to be in the order of 1%, leads to an estimate of 1 launch in 10,000 or, at current rates, about 1 launch in 500 years which might involve the the ocean impact of an intact vehicle.**

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* In-flight failures occasionally destroy the vehicle before the destruct system can be activated, and it is possible that failures other than in the destruct system may disable or limit the capability of the destruct system.

** The probability of failure of an Atlas during the first 148 seconds of flight has been estimated as 0.8%. The probability of the destruct system failing to operate in this same period has been estimated as 0.1%, given a combined probability of about 8 simultaneous failures per million launches.[34]

In view of the uncertainty concerning the quantities of propellant that might reach the ocean in an abort, and the probablistic nature of parts of the problem, estimates of the maximum radius at which the MAC would occur have been made for propellant quantities ranging from 1% to 100% of the total vehicle propellant load. The radii were estimated from the same two diffusion models considered previously.[29,30] Diffusion coefficients were estimated from experimentally-determined values for quiescent systems reported in the literature.[30]

Calculations were made for a Titan IIIE (or Titan IIIC) failure before ignition of Core I, and for a Delta failure before ignition of the second stage (worst cases). Figures 5 and 6 present results of these calculations.

It appears that a near-shore (shallow water) impact of one of these vehicles intact might be regarded as a significant environmental event. As noted above, however, such an extreme event is not considered likely. It would require the simultaneous early failure of the vehicle (estimated at perhaps 1% probability), and failure of the vehicle destruct system (probability estimated to be less than 1%), and additionally, the physically unlikely situation of the hypergolic propellants failure to ignite following rupture of the propellant tanks on impact. Consequently, minimal significance is attached to such an event.

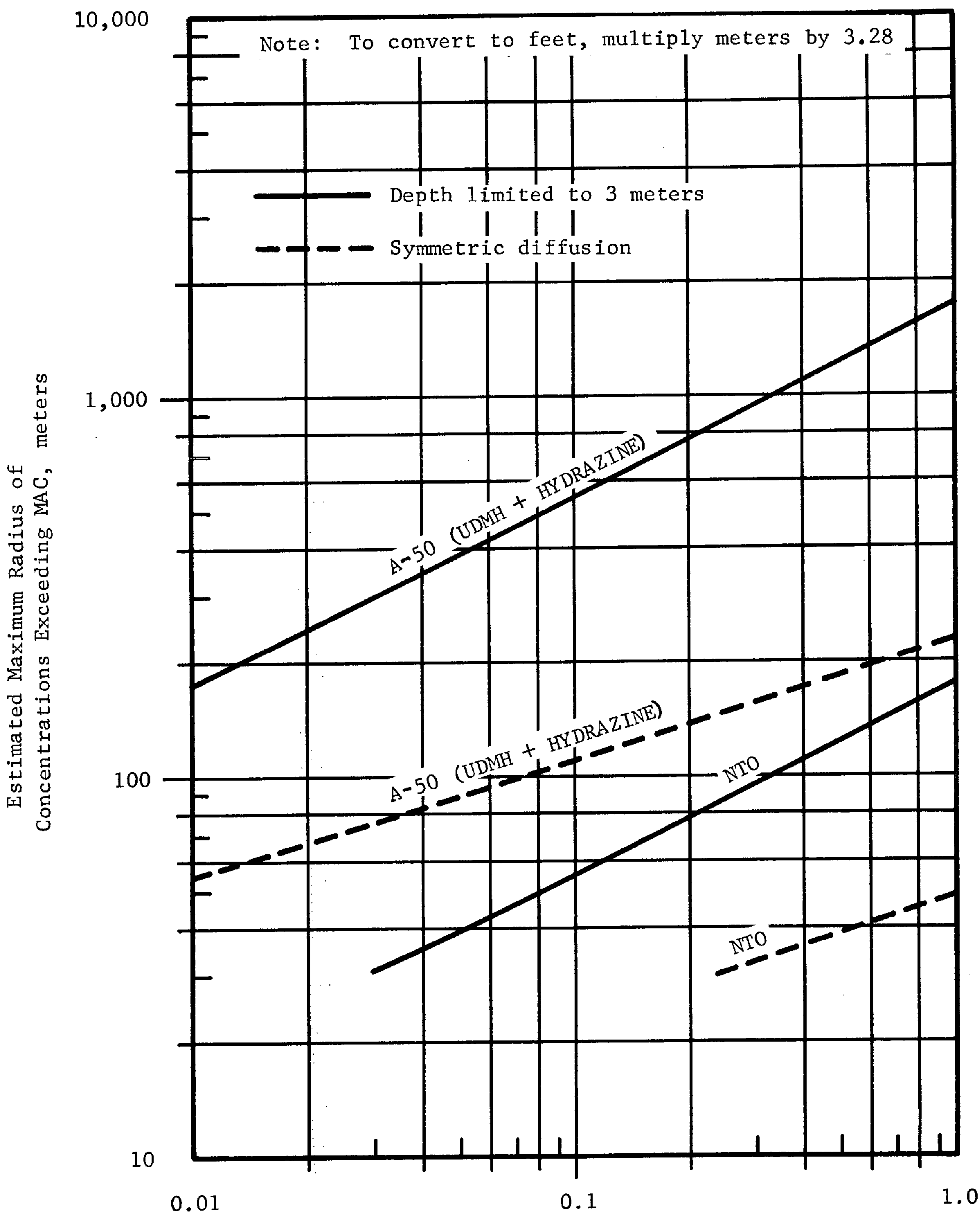

FIGURE 5. ESTIMATED MAXIMUM RADIUS AT WHICH THE MAC IS EXCEEDED FOR WORST-CASE TITAN IIIE/CENTAUR OR TITAN IIIC ABORTS

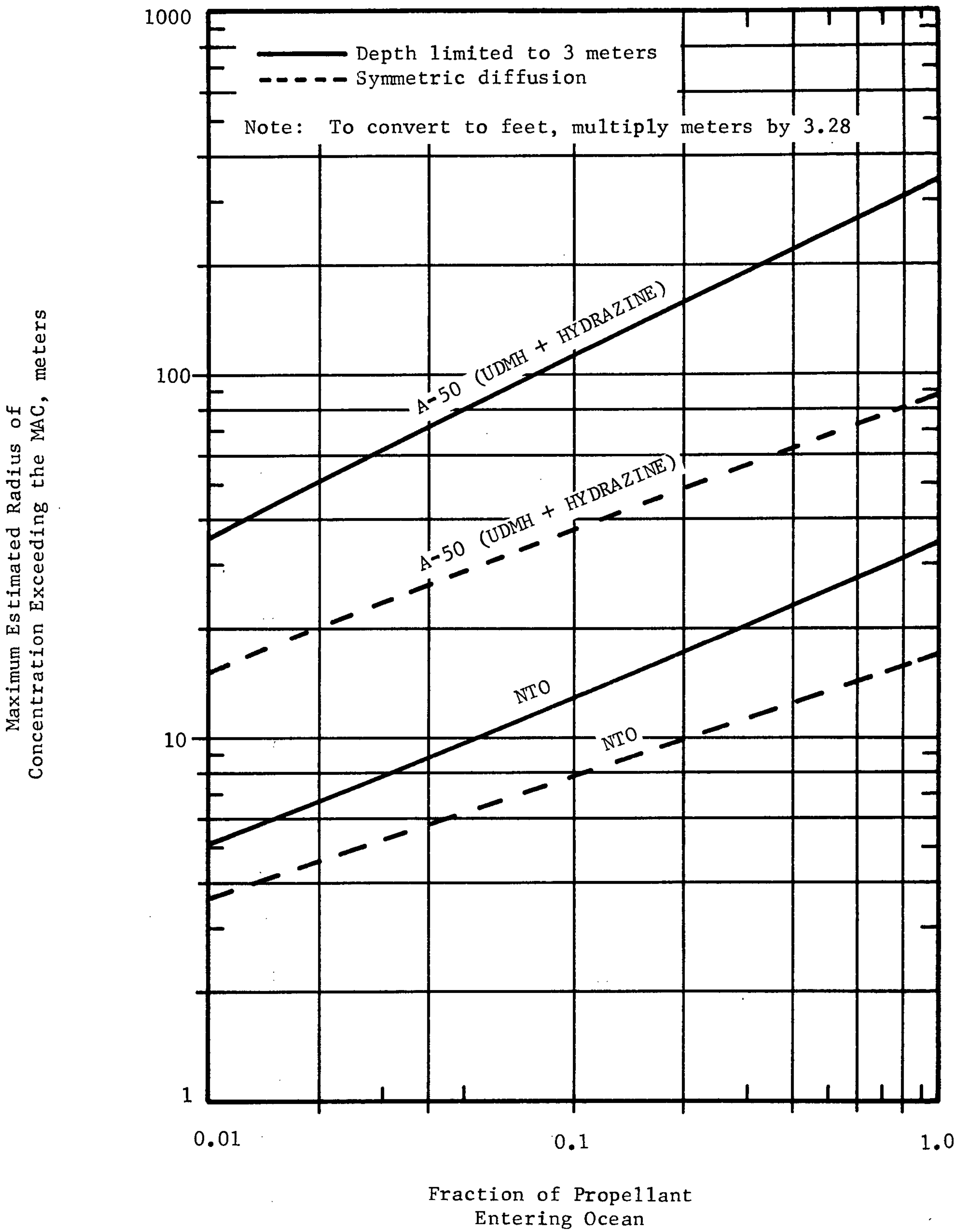

FIGURE 6. ESTIMATED MAXIMUM RADIUS AT WHICH THE MAC IS EXCEEDED FOR WORST-CASE DELTA ABORTS

Titan III or Delta second stage fuels and oxidizer which actually reached the ocean would ultimately end as biologically inert compounds or compounds such as found in commercial fertilizers.

The oxidizer for Titan III and the Delta second stage, N_2O_4, reacts with water to form nitric acid which then forms ionic compounds, such as sodium nitrate, a commercial fertilizer, with minerals in the sea water. Hydrazine and unsymmetrical dimethyl hydrazine (UDMH), the components of Titan III and Delta fuel, degrade over a period of hours in pure water in contact with the atmosphere.[(35)] Their degradation is hastened by the presence of minute amounts of metal ions such as F_e^{+++}, Cu^{++}, Al^{+++}, Cr^{+++}, and Ni^{++}[(36)], all of which are present in sea water.

The fundamental reaction of the decomposition of aqueous hydrazine in contact with the atmosphere is $3N_2H_4 \rightarrow 2NH_3 + 2N_2 + 3H_2$ (after Reference 36). As the pH is reduced, more ammonia is produced and at high pH more gaseous nitrogen and hydrogen are produced. Ammonia is a commercial fertilizer and gaseous nitrogen and hydrogen represent no biological hazard. Another potential reaction is with carbon dioxide dissolved in sea water to form carbazic acid which can decompose to CO_2 and the hydrazine salt of the acid. Hydrazine salts also decompose in the manner of the fundamental equation in basic solutions in contact with the atmosphere (Reference 35). Thus, any hydrazine released in the ocean, which is unable to react with the N_2O_4 oxidizer, will be degraded over a short period of time to less toxic compounds. UDMH, while not as extensively studied, undergoes similar reactions.

The early abort of an Atlas or Thor, which resulted in the entire load of RP-1 or RJ-1 being released into the ocean would result in a surface film covering a maximum of 55,740 square m[31,32]. Evaporation of such thin films is rapid. The time for complete evaporation has been calculated as 59 hours for favorable conditions (wind velocity of 5m/sec) or 206 hours for unfavorable conditions (wind velocity of 1 m/sec).[32] Due to the relatively small area involved and the fleeting nature of the phenomena, no significant environmental effect is expected. As discussed previously, the probability of such an event is regarded as very low.

In summary, water pollution resulting from the operation of launch vehicles for NASA automated missions is expected to be insignificant except for worst-case situations involving highly unlikely combinations of events. Even should such a situation occur, the effects are not persistent, i.e., the toxicants will disperse and degrade to values below the MAC's within a few days to a few weeks. Because of the non-isolation of the areas involved and the lack of persistent effects, needed repopulation should occur rapidly.

NOISE

Source and Nature

Significant noise levels are generated in the operation of rocket engines and launch vehicles. The major source of this acoustic disturbance appears to be the jet noise, although a significant contribution may derive from the combustion process. Both the acoustic power emitted and the frequency spectrum of the noise is affected by the size of the rocket engine (thrust level) and the specific impulse of the engine, as well as by design details.

An approximate relationship between the vehicle thrust level and the generated sound pressure level is shown in Figure 7. Thrust levels of the vehicles considered in this Environmental Statement are indicated on the figure.

The nature of the noise may be described as intense, relatively short, composed predominantly of low frequencies, and infrequent (approximately 20 times per year, including all launch sites). Table 10 shows peak sound intensity levels resulting from Atlas and Titan launches at the closest press sites and the nearest site boundaries. These are the largest, and, thus, the noisiest, of the vehicles considered here.

TABLE 10. PEAK SOUND PRESSURE LEVELS (SPL) RESULTING FROM ATLAS AND TITAN IIIC/TITAN IIIE LAUNCHES (Median/Upper Bound)

Vehicle	SPL at Nearest Press Site (dB)	SPL at Nearest Boundary (dB)
Atlas[a]	106/116	102/110
Titan IIIC/IIIE[b]	118/123	112/117

(a) Based on 4 Atlas launches.[38]
(b) Based on 2 Titan IIIC launches.[39]

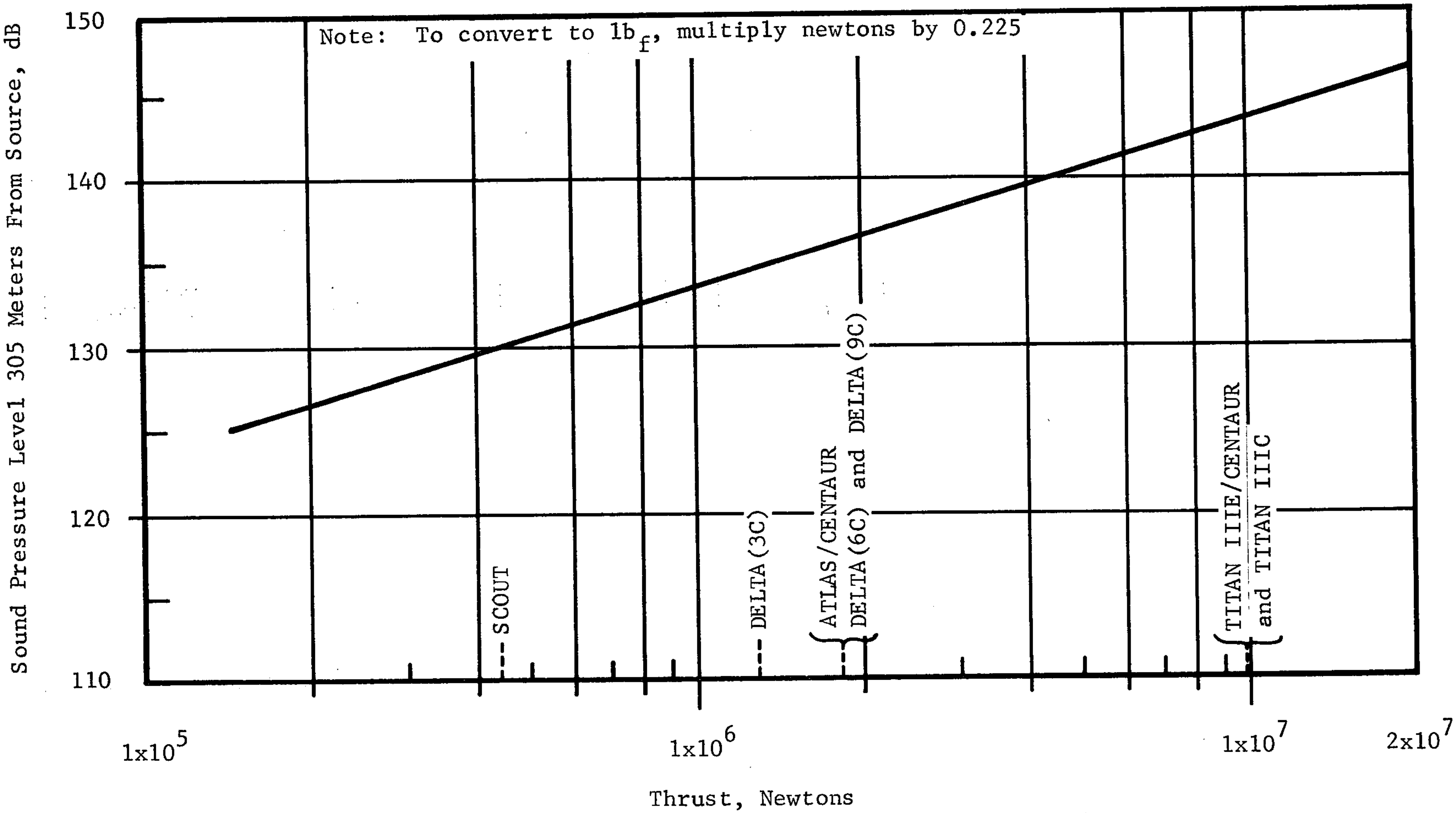

FIGURE 7. APPROXIMATE RELATIONSHIP BETWEEN VEHICLE THRUST AND SOUND PRESSURE LEVEL AT A FIXED DISTANCE (Adapted from Reference 37)

A typical time-intensity history is shown in Figure 8. The total duration of the noise is generally 3 to 4 minutes. A frequency-intensity spectra is shown in Figure 9. Note that the lower frequencies predominate and that the higher frequencies are attenuated more rapidly with distance. This means that the lower frequencies travel farther and affect a greater area. These lower frequencies are less harmful to human hearing, and are less annoying[40], but are the prime cause of structural damage[37].

Impact on the Environment

Noise can affect the environment, with its most important effects on man and on physical structures. For this reason, these effects are used here as the criteria for examining the impact of booster noise.

Noise can affect man physiologically and psychologically. Physiologically, high-intensity noise can cause permanent hearing damage and temporary threshold shift, i.e., the sensitivity of hearing is temporarily lowered. Psychologically, noise can create feelings of annoyance and discomfort in some people, while for other people the same noise can create excitement and pleasure. Research on the effect of noise on man has yielded criteria for noise levels and durations which man can generally tolerate. Table 11 shows consensus values of a set of tolerance limits. The Damage Risk Values are thresholds beyond which hearing damage might occur. These thresholds correspond to an integrated "acoustic dose" of about 12 millibar-seconds at the lower intensities, dropping to about 6 millibar-seconds at 130 dB. Table 12 compares the integrated acoustic exposures corresponding to the upper bounds of Table 10 with these threshold criteria.

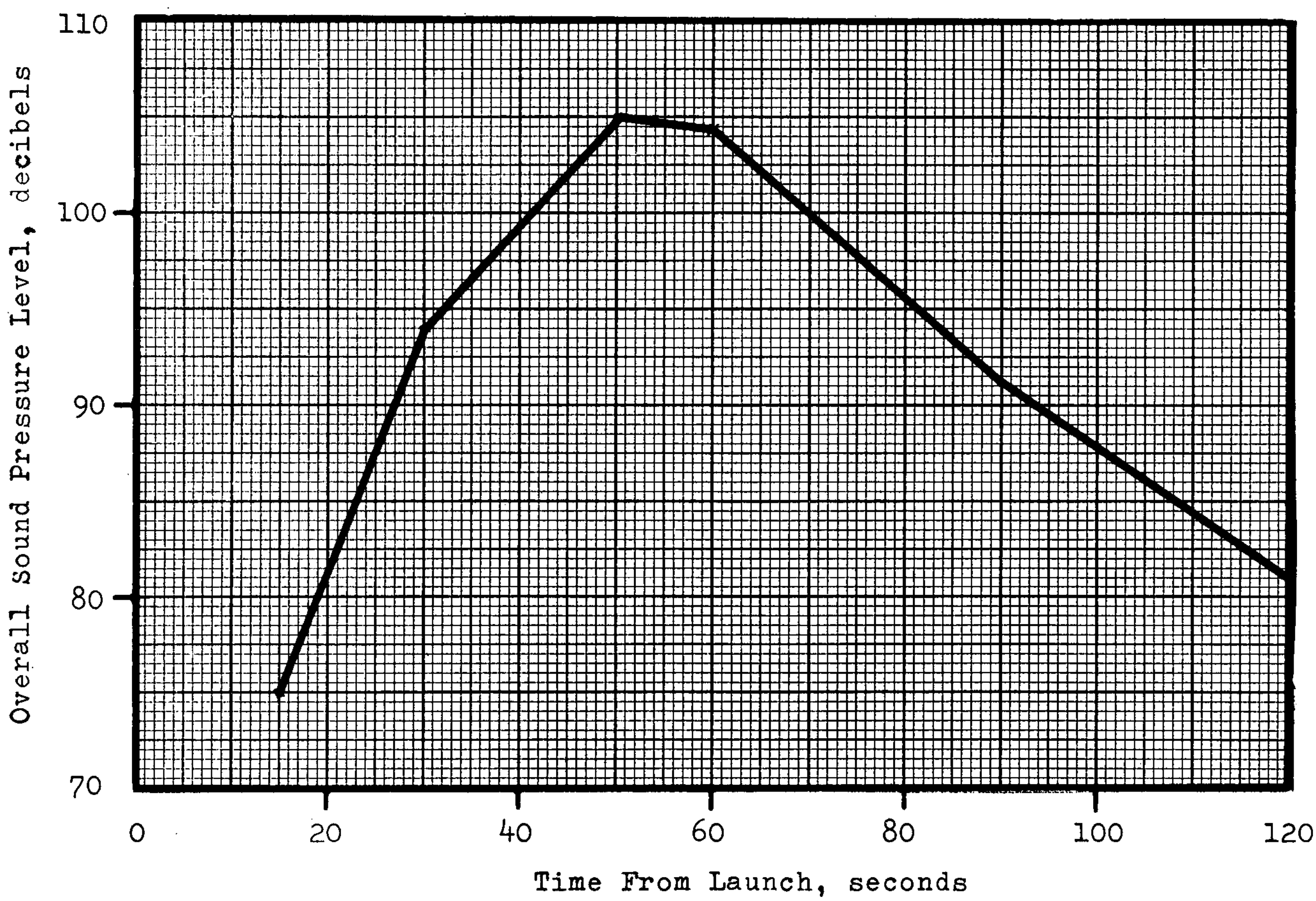

FIGURE 8. OVERALL SOUND PRESSURE LEVELS AT A DISTANCE OF 7,710 METERS FROM AN ATLAS LAUNCH AS A FUNCTION OF TIME (Adapted from Reference 38)

Note: To convert to feet, multiply meters by 3.28

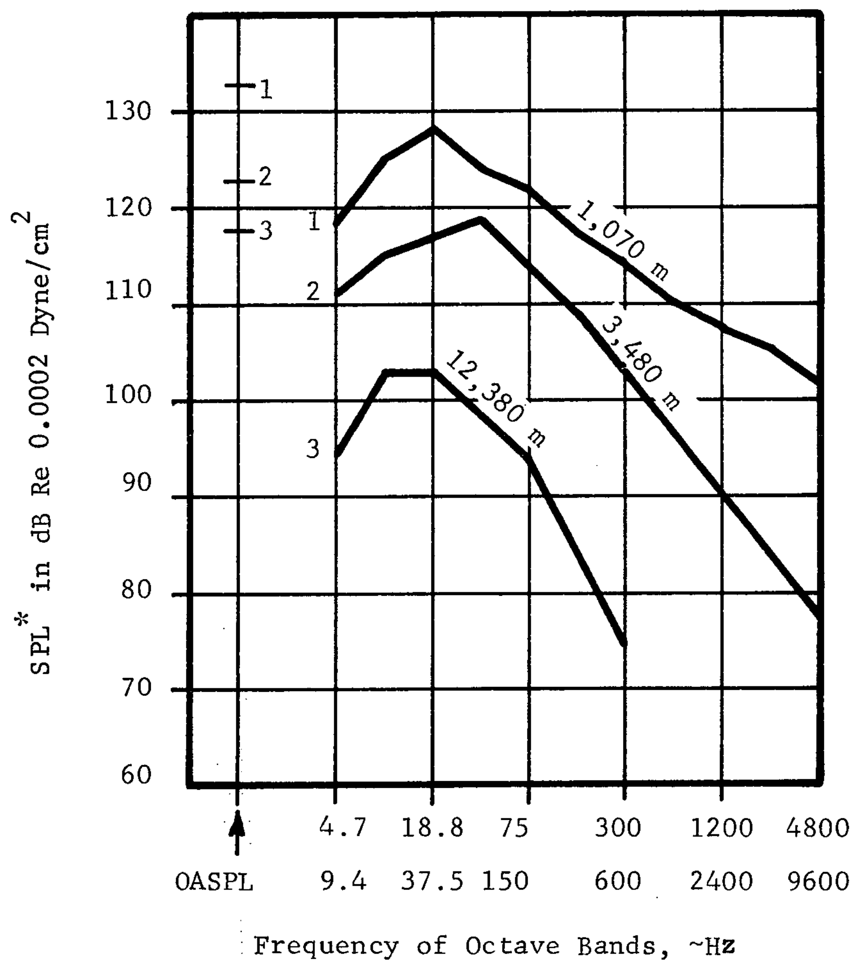

FIGURE 9. MAXIMUM, FREE-FLIGHT, SPL SPECTRA FOR A SATURN TEST AT THREE DISTANCES (38)

* Sound Pressure Level

TABLE 11. NOISE LEVELS FOR DAMAGE RISK AND ANNOYANCE (37,40)

Damage Risk Values (in dB)	Annoyance Threshold	Damage to Ground Structures Threshold
130 (10 seconds tolerance)	90 dB(A)	130 dB (frequencies lower than 37 Hz)
125 (30 seconds tolerance)		
120 (60 seconds tolerance)		

TABLE 12. ACOUSTIC DOSE RESULTING FROM ATLAS AND TITAN IIIE/TITAN IIIC LAUNCHES

	Press Box	Nearest Boundary	Press Box	Nearest Boundary
	Atlas		Titan	
Peak SPL, dB	116	110	123	117
Integrated Acoustic Dose*, millibar-seconds	1.78	1.14	4.34	2.84
Threshold Dose, millibar-seconds	12	12	11.5	12

* Integrated by means of the average duration-distance-intensity relationships of Reference 38 to a level 20 dB below the peak level.

It is clear that a substantial margin of safety exists for any unprotected persons exposed to the noise associated with these rocket launches.

Structural damage is possible with high-intensity noise composed, predominantly, of low frequencies. Measurements of the sound pressure levels associated with Saturn IB launches[41] showed peak values of about 120 dB below 37 Hz at a distance of 2,362 m. Measurements at Atlas launches showed this intensity level at a distance of about 1,524 m[38]. Comparing the damage criteria shown in Table 11 with these intensity levels, structural damage would not be expected outside of a 0.9 to 1.8 km radius from launch. Only resistance structures are located within these short distances from the launch pads.

For any single launch vehicle test or launch, "noise pollution" occurs over a relatively wide area. However, with its short total duration of 3 to 4 minutes, its infrequent occurrence (~20 times a year, including all sites), and the imposed safety precautions, the noise from these boosters cannot be considered to have a significant impact on the environment. No uncontrolled areas are close enough to the launch pads for any significant effects to result from exposure of the public or uncontrolled-area structures to these noise levels.

At distances corresponding to the closest permitted approach by any uncontrolled or unprotected person, the peak noise level generated by rocket launches is comparable to that produced by a four-engine jet aircraft at 150 m overhead. Unmuffled motorcycles, construction noise (compressors and hammers), and some rock and roll bands closely approach this noise level. This noise level is exceeded by pneumatic riviters and chippers in close proximity and within a boiler shop at maximum noise levels.

REENTRY DEBRIS

In the usual launch of an Earth satellite, one or more launch vehicle stages are placed in orbit. Over a period of time, small drag forces resulting from the tenuous atmosphere at orbital altitudes will cause the orbit to decay. The time period before the object reenters the denser portion of the atmosphere may range from one orbital revolution to many years, depending upon initial orbit and the ballistic coefficient.

Of the stages in orbit at present, the next five years will see the reentry of seven larger rocket bodies with combined weight of approximately 5,440 kg and five smaller rocket bodies with combined weight of approximately 195 kg. Upon reentry, these will break up into fragments of various size. The majority of fragments will burn up during entry. Except within limits of latitude determined by orbital inclination, we are unable to predict in advance of the launch where the surviving pieces will fall.

From 1967 to the present time, 23 rocket bodies placed in orbit by the launch vehicles covered in this statement reentered the Earth's atmosphere. The total weight of these bodies before reentry was approximately 102,500 kg. More than 10 times as many other rocket bodies reentered during the same period from all sources. No casualties, injuries or property damage are known to have resulted from impact of any surviving fragments. Fewer than a dozen fragments, ranging in weight up to about 59 kg, have been found. Launches by these cited launch vehicles in the 1970's are expected to add potential orbital debris at a rate no greater than that of the past.

Based on worldwide experience to date, the extent of the hazard from orbital debris is considered small.

ALTERNATIVES

As indicated previously, the launch vehicle activities which contribute to potential environmental impact are the development and testing of propulsion systems and the launch of space vehicles. The matrix in Table 13 displays some of the alternative actions which might be taken in these areas. The only alternative which could be applied on a short-term basis (1-3 years) would be preferred use, when possible, of the "cleaner" of current launch vehicles. However, this would have only a minor effect on total emissions and would involve significant expense and/or have significant effects on spacecraft delivery capability.

In the long-term, a possibly attractive alternative to current vehicles would be the development and use of LOX/LH_2 stages to replace current vehicle stages. Such a development might cost \$250M-\$500M per stage and require five or more years. It should be noted that such stages would still be expendable and not offer the cost advantages expected for the space shuttle, which is expected to replace most of the expendable vehicles in the 1978-1980 period.

In view of the limited environmental impact of the current vehicles and the expected introduction of the space shuttle, no further analysis of any of the above alternatives would be recommended.

TABLE 13. MATRIX OF ALTERNATIVES

Activity \ Alternative	Use of Scrubbers, Collectors, etc.	Use of Remote Sites	Development of "Clean" Solid Propellants	Replacement of All Solid Propellant and NTO/A-50 Lower Stages by LOX/ Kerosene Stages	Replacement of All Lower Stages by LOX/LH_2 Stages
Research, Development, and Ground Test	Potentially complete elimination of objectionable emissions.	Already reasonably remote. No effect on global basis.	Reduction or elimination of HCl emissions.	Elimination of HCl emissions. Possible reduction of NO emissions. Reduced impact of accidents.	Elimination of most objectionable emissions. Little or no effect on noise. Effect on NO emission uncertain. Reduced impact of accidents.
Launch	Practical only for first few meters of flight.	Already reasonably remote. Few alternative sites available. No effect on global basis.	Reduction or elimination of HCl emissions.	Elimination of HCl emissions. Possible reduction of NO emissions. Reduced impact of accidents.	Elimination of most objectionable emissions. Little or no effect on noise. Effect on NO emission uncertain. Reduced impact of accidents.
Comment	Increased development and operational expense. Modest overall reduction in emissions.	Extremely expensive.	No formulations known with performance comparable to current solid propellants. Would require motors of increased size and thus increased objectionable emissions other than HCl.	Non-recurring expense of perhaps \$300M-500M. Some recurring cost increase. Modest effect on overall emissions.	Non-recurring expense of perhaps \$1,000M. Recurring cost increase by factor of, perhaps, 2 or more.

THE RELATIONSHIP BETWEEN THE LOCAL SHORT-TERM USES OF THE ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY

In fulfilling its responsibility, NASA OSS has followed a philosophy that has always emphasized safety, reliability, and economy in space transportation. Recent studies of the relevance of specific automated space program objectives to broad national goals have helped to identify and document the value of these programs in relation to mankind's historical need to better understand, utilize, predict, protect, and control his life-sustaining and, yet at times, hostile environment.[42,43]

It is impractical here to itemize all known and potential environmental benefits generated by past or planned space activities, but the general value can be simply expressed as follows. Scientifically, we have learned more about our immediate environment and that of the solar system since the inauguration of the space age than in all previous ages combined. Such knowledge is fundamental to any realistic endeavor to protect the environment. Technically, we are making slow but noticeable improvement in our ability to utilize this recently acquired space capability for such pedestrian and necessary functions as communications, navigation, and meteorology. Perhaps of most significance to maintenance and enhancement of long-term environmental productivity is the current NASA thrust in the area of orbital Earth resource surveys. This embryonic effort has a unique potential for providing mankind with an operational capability to measure, monitor, and manage environmental conditions and natural resources from a local to a global scale.

NASA automated missions represent passive payloads which in themselves have no adverse environmental impact aside from that associated with items in space, reentry items, and the launch process. Reentry items and the launch process represent minor transient effects while items remaining permanently in outer space have no impact on the Earth and its atmosphere. On the other hand, some systems launched into space make immediate contributions to the betterment of mankind while others are directed toward long-term benefits to the Earth, its environment, and inhabitants.

IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES

The materials which make up a launch vehicle as it sits on the pad ready for launching are largely irretrievable once the launch process is initiated. However, they are relatively easily replaced and, in general, are replaceable from domestic resources with relatively insignificant expenditure of manpower and energy.

By far the largest weight of materials making up a launch vehicle is the propellants. These have previously been enumerated and defined; they are common chemicals, petroleum-derived hydrocarbons, and liquified atmospheric gases. Resources and energy required for their production are insignificant in comparison with, for example, the resources and energy required to produce 1 million barrels of jet fuel per week, the current production rate for private, commercial, and military jet aircraft.

In the use of cryogenic propellants, it has been the practice to use both liquid and gaseous helium for various purposes including tank pressurization. For example, the Centaur vehicle requires about 6,825 cubic meters of helium from test through launch.(44) Helium is often considered to be a valuable natural resource that requires conservation. The estimated amounted of recoverable helium is about 5 billion cubic meters with a current annual usage rate of about 28 million cubic meters.(45) At current rates, use for all NASA purposes approximates 3.4 million cubic meters per year.(46) The actual usage attributable to the vehicles considered here is small. At current use rates, many years of supply are available.

After propellants, the next largest amounts of materials are iron and aluminum. Other materials include plastics and glass, as well as other metals such as nickel, chromium, titanium, lead, zinc, copper, etc.* There may be small amounts of silver, mercury, and the noble metals, gold and platinum. The quantities of materials of various kinds which are utilized are insignificant in comparison with those used in one year of production (10,000,000) of automobiles, for example.**

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* The composition of a "typical" launch vehicle can be estimated as 78.3% steels, 20.2% Al, 0.4% Ti, and 1.2% miscellaneous.(47)

** In the period 1969-1971, including all launches planned for 1971, the total hardware weight used in NASA launch vehicles for automated space missions was the equivalent of about 76 automobiles per year.

Perhaps the best available measure of the commitment of resources to NASA launch vehicles for automated space missions is the annual rate of dollar expenditure on such vehicles. This is expected to average approximately $150M in the period 1970-1976.[48] By far the largest fraction of these expenditures are for wages and salaries. These expenditures represent a relatively trivial fraction of the national economy. As illustrated by this and the other examples given, no commitment of any individual resource of major significance to the national economy exists.

APPENDIX A

REFERENCES

(1) "Launch Vehicle Performance File", NASA OSSA Launch Vehicle and Propulsion Programs (Code SV), Report No. BMI-NLVP-DD-70-1, March 2, 1970, by R. R. Teeter, A. E. Weller, and D. S. Edgecombe.

(2) "Launch Vehicle Performance Document", NASA OSSA Launch Vehicle and Propulsion Programs (Code SV).

(3) Letter to the Honorable Clinton P. Anderson, Chairman, Committee on Aeronautical and Space Sciences, U. S. Senate; from James C. Fletcher, NASA Administrator; September 29, 1971.

(4) "Threshold Limit Values of Airborne Contaminants and Physical Agents With Intended Changes", American Conference of Governmental Industrial Hygienists, 1971.

(5) "Compendium of Human Responses to the Aerospace Environment", Vol. III, NASA CR-1205(III), November, 1968.

(6) "Guide for Short-Term Exposure of the Public to Air Pollutants: II Guide for Hydrogen Chloride", Advisory Center on Toxicology, National Academy of Science-National Research Council, August, 1971.

(7) "Air Quality Criteria for Carbon Monoxide", U. S. Department of Health, Education and Welfare, March, 1970, Publication AP-62.

(8) Federal Register, October 23, 1971, Vol. 36, No. 206, page 20513.

(9) Note from Advisory Center on Toxicology, National Academy of Science-National Research Council, April, 1971.

(10) "Guide for Short-Term Exposure of the Public to Air Pollutants: I Guide for Oxides of Nitrogen", Advisory Center on Toxicology, National Academy of Science-National Research Council, April, 1971.

(11) Craig, R. A., The Upper Atmosphere--Meteorology and Physics, Academic Press, New York, 1965.

(12) Valley, S. A. (Ed.), "Handbook of Geophysics and Space Environments", Air Force Cambridge Research Laboratories, Office of Aerospace Research, 1965.

(13) Weller, A. E., "Estimate of Nitrogen Oxide Formation from Nitrogen Impurity in Propellant Oxygen", BMI-NLVP-ICM-72-38, Battelle Columbus Laboratories, April 25, 1972.

(14) Dumbauld, R. K., Bjorklund, J. R., Cramer, H. E., and Record, F. A., "Handbook for Estimating Toxic Fuel Hazards", NASA CR-61326, April, 1970.

(15) Dumbauld, R. K., and Bjorklund, J. R., "Hazard Estimates for Selected Rocket Fuel Components at Kennedy Space Center", NASA CR-61358, May 5, 1971.

(16) Turner, D. B., "Workbook of Atmospheric Dispersion Estimates", Public Health Service Publication No. 999-AP-26, 1967.

(17) Kellogg, W. W., "Pollution of the Upper Atmosphere By Rockets", Space Science Reviews 3 (1964), pp 275-316.

(18) Barth, C. A., "Nitrogen and Oxygen Atomic Reactions in the Chemosphere", Paper given at the International Symposium on Chemical Reactions in the Lower and Upper Atmosphere, San Franciso, California, 1961.

(19) "The Earth's Ionosphere", NASA SP-8049, March, 1971.

(20) Hage, K. D., Browne, N. E., and Hilst, G. R., "Preliminary Estimates of Environmental Exposure for Fuel and Exhaust Products", NASA CR-61056, January, 1965.

(21) Cramer, H. E., Dumbauld, R. K., Record, F. A., and Swanson, R. N., "Titan IIID Toxicity Study", Report No. TR-70-3-A, GCA Corporation, June, 1970.

(22) McKee, J. E., and Wolf, H. W., "Water Quality Criteria", The Resources Agency of California, State Water Quality Control Board, Publication #3-A, 1963.

(23) Riddick, J. A., and Banger, W. B., Techniques of Chemistry, Vol. II, Wiley Interscience, 1970, (3rd Edition).

(24) King, C. A. M., An Introduction to Oceanography, McGraw Hill Book Company, New York, 1913.

(25) Fairbridge, R. E., Editor, The Encyclopedia of Oceanography, Reinholt Publishing Corporation, New York, 1966.

(26) Odum, H. T., et al., Coastal Ecological Systems of the United States, Institute of Marine Sciences, University of North Carolina, 1969, p. 526-545.

(27) U. S. Coast and Geological Survey Charts.

(28) National Geographic Society Charts.

(29) Crank, J., <u>The Mathematics of Diffusion</u>, Oxford, 1956.

(30) Perry, R. H., Chilton, C. H., and Kirkpatrick, S. D. (Editors), <u>Chemical Engineers Handbook</u>, 4th Edition, McGraw-Hill, 1964.

(31) Blokker, P. C., "Spreading and Evaporation of Petroleum Products on Water", Int. Harbour Congress, 4th, Verslagebock, Compte Rendu (Proceedings, Tagungsbuch) Antwerp, 1964.

(32) Geankoplis, C. J., "Spreading and Vaporization of Rocket Propellant on Water", Battelle Columbus Laboratories, Report Number BMI-NLVP-IM-72-2, February 18, 1972.

(33) Memorandum, NASA, RY/T. Kerr to NASA SPS/J. Rosenberry, December 21, 1971.

(34) "Pioneer F AEC Safety Study Phase II, Range Safety Equipment, Launch Pad Hazards, Launch Vehicle Failure Probabilities and Reentry Environment", Report No. GDC-BTD70-015, General Dynamics Convair Aerospace Division, January 18, 1971.

(35) Audrieth, L. F., and Ogg, B. A., <u>The Chemistry of Hydrazine</u>, John Wiley & Sons, Inc., New York, 1951.

(36) Clark, C. C., <u>Hydrazine</u>, Mathieson Chemical Corporation, Baltimore, Maryland, 1953.

(37) Regier, A. A., Mayes, W. H., and Edge, P. M., Jr., "Noise Problems Associated with Launching Large Space Vehicles", Sound, No. 6, 7-12 (1962).

(38) Cole, J. N., Powell, R. G., and Hill, H. K., "Acoustic Noise and Vibration Studies at Cape Canaveral Missile Test Annex, Atlantic Missile Range, Volume 1, Acoustic Noise", Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, TR 61-608(1), 1962, AD296852.

(39) Cesta, R. P., and McLouth, M. E., "Launch Conditions Produced by the Titan III-C Launch Vehicle", American Industrial Hygiene Association Journal, Vol. 30, pp 635-639, 1969.

(40) Kryter, K. D., <u>The Effects of Noise on Man</u>, Academic Press, New York (1970).

(41) Hitchcock, V. G., and Timmons, W. R., "Saturn I Block II Launch Acoustical Environmental Summary", Report No. TR-284, John F. Kennedy Space Center, March 15, 1966.

(42) Lederman, L. L. and Windus, M. L., "An Analysis of the Allocation of Federal Budget Resources as an Indicator of National Goals and Priorities", Parts I and II, Prepared by Battelle's Columbus Laboratories, Columbus, Ohio, for NASA Office of Space Science and Applications, February 10, 1969, Report No. BMI-NLVP-TR-69-1.

(43) Wukelic, G. E., and Frazier, N. A., "Selected Space Goals and Objectives and Their Relation to National Goals", Prepared by Battelle's Columbus Laboratories, Columbus, Ohio, for NASA Office of Space Science and Applications, July 15, 1969, Report No. BMI-NLVP-TR-69-2.

(44) Estimated provided by R. Schmidt, NASA, Code SV, November 12, 1971.

(45) Monograph on Liquid Helium Technology, National Bureau of Standards, 1968.

(46) Estimate provided by W. R. Harwood, NASA Code BXE, October 5, 1971.

(47) Teeter, R. R., "Hardware Weight and Composition for Selected Launch Vehicles", BMI-NLVP-ICM-72-29, Battelle Columbus Laboratories, March 27, 1972.

(48) Memorandum from S/Associate Administrator for Space Science and Applications to A/Administrator, "Program Operating Plan 71-1", May 13, 1971.

APPENDIX B

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EXAMPLE TRAJECTORY ELEVATIONS AND IMPACT POINT MAPS

Figures B-1 through B-7 present the relationships between ground range and altitude for the seven vehicles considered in this Environmental Statement. Also shown on these figures are the separation points of jettisoned hardware (spent stages, shrouds, etc.) and the corresponding impact range.

Figures B-8 through B-14 are maps of example impact point loci for the seven vehicles for each site from which the vehicle is launched. The locations of the impact points of jettisoned hardware are shown on these maps.

Plots of the impact points have been terminated at a range of approximately 7,000-9,000 kilometers. At conditions corresponding to such impact ranges, the quantity of propellant remaining in the vehicle is small, and the re-entry of an intact stage is unlikely. Also, as the impact range increases and the re-entry angle becomes small, the exact location of the impact point is increasingly influenced by details of the aerodynamics of the re-entering object, and thus is relatively indeterminate in a generalized sense. It should also be noted that as the vehicle approaches orbit, the instantaneous impact point sweeps down range at extremely high speeds. For example, the instantaneous impact point for a Scout launched easterly from Wallops Island (see Figure B-8) crosses West Africa at a speed greater than 185 kilometers per second (667,000 kilometers per hour).

The ground range-altitude plots and the impact point loci shown in this Appendix should be regarded as examples. They were developed from previously published information[(1)].

Nearly every mission launched is unique in some sense, and vehicle trajectories are designed to satisfy the unique requirements of the mission. For every launch, trajectories and impact point loci are calculated at a level of detail impossible for the generalized treatment required here. Full consideration is given to the location of the impact points of jettisoned hardware and to the path followed by the instantaneous impact point. When necessary, trajectories may be modified to control the impact point of jettisoned hardware and to control the path of the instantaneous impact point.

Note: To convert to feet, multiply meters by 3.28
To convert to nautical miles, multiply kilometers by 0.54

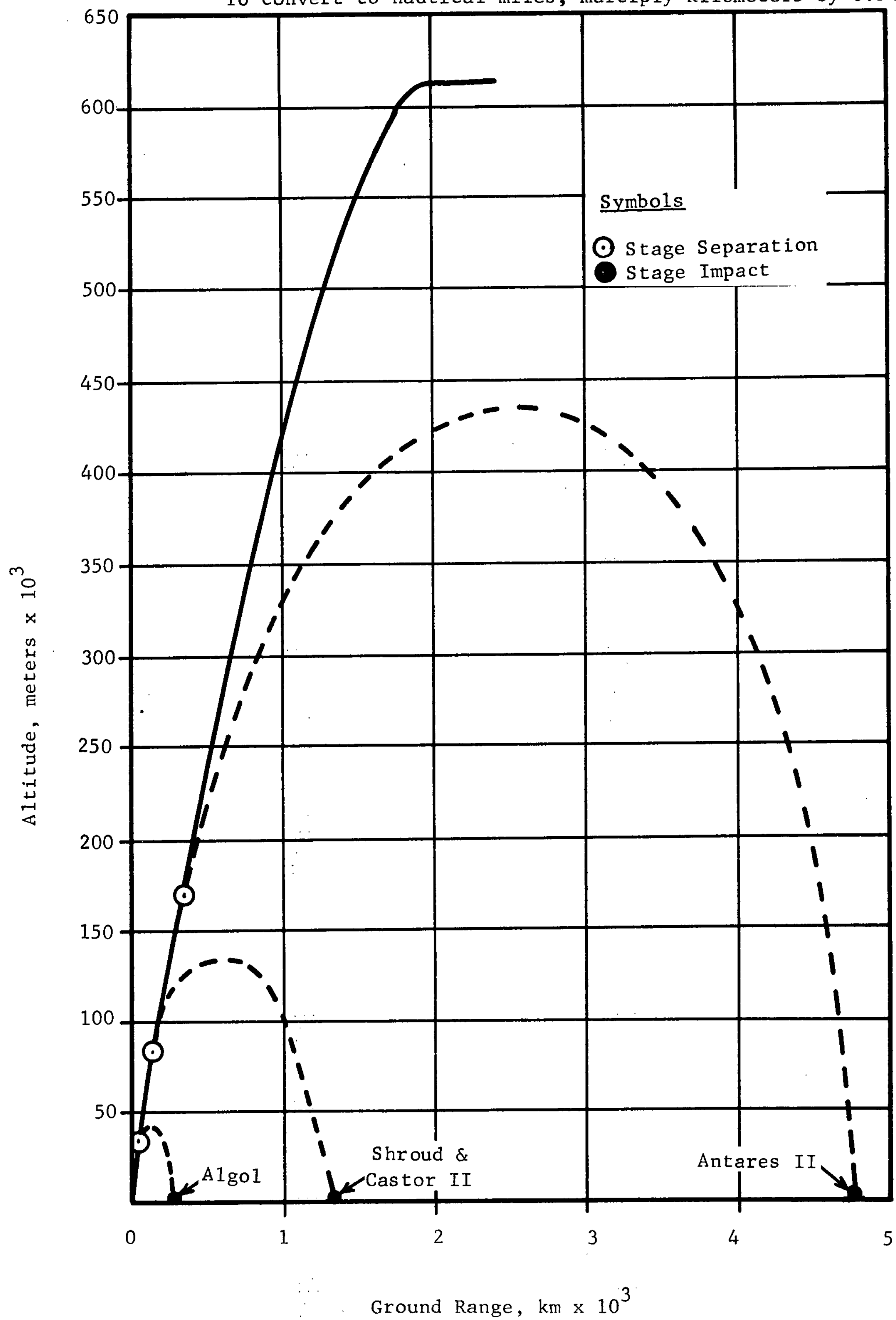

FIGURE B-1. EXAMPLE TRAJECTORY ELEVATION FOR SCOUT

Note: To convert to feet, multiply meters by 3.28
To convert to nautical miles, multiply kilometers by 0.54

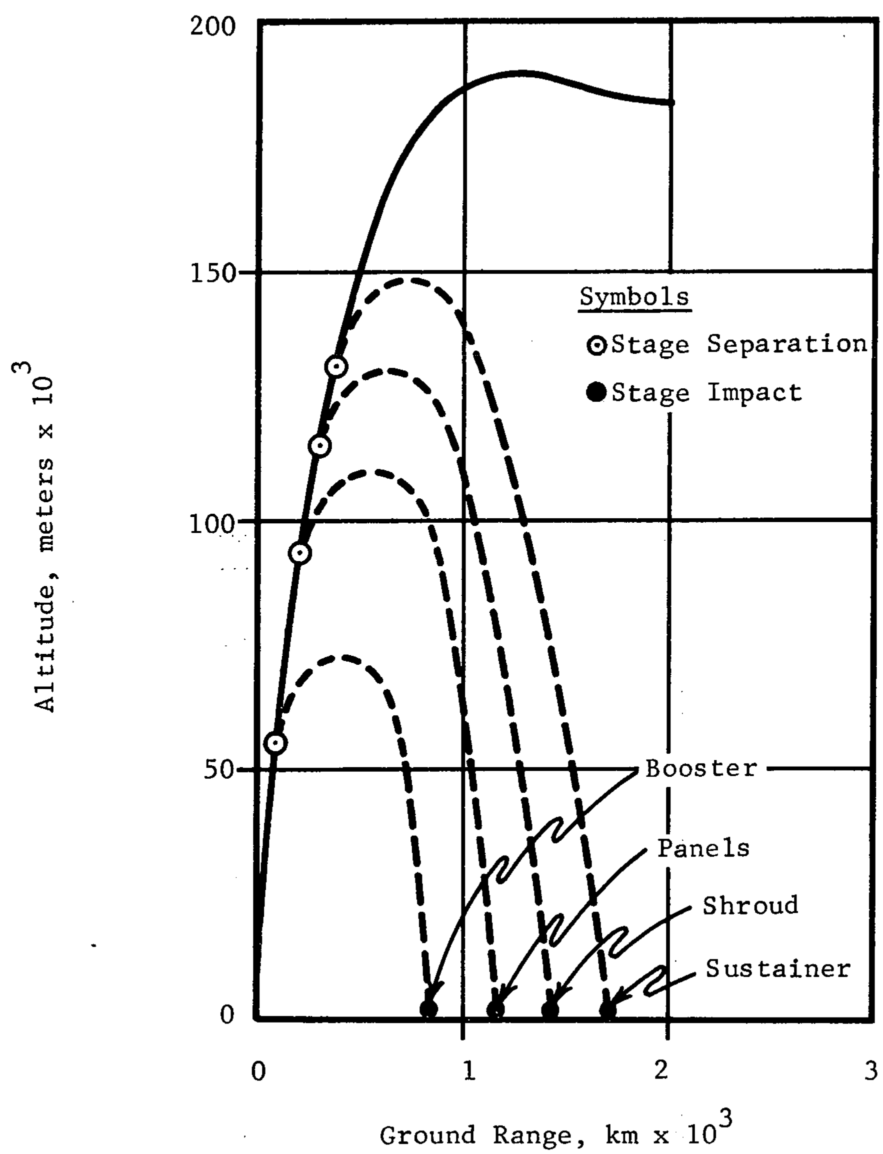

FIGURE B-2. EXAMPLE TRAJECTORY ELEVATION FOR SLV3D/CENTAUR

Note: To convert to feet, multiply meters by 3.28
To convert to nautical miles, multiply kilometers by 0.54

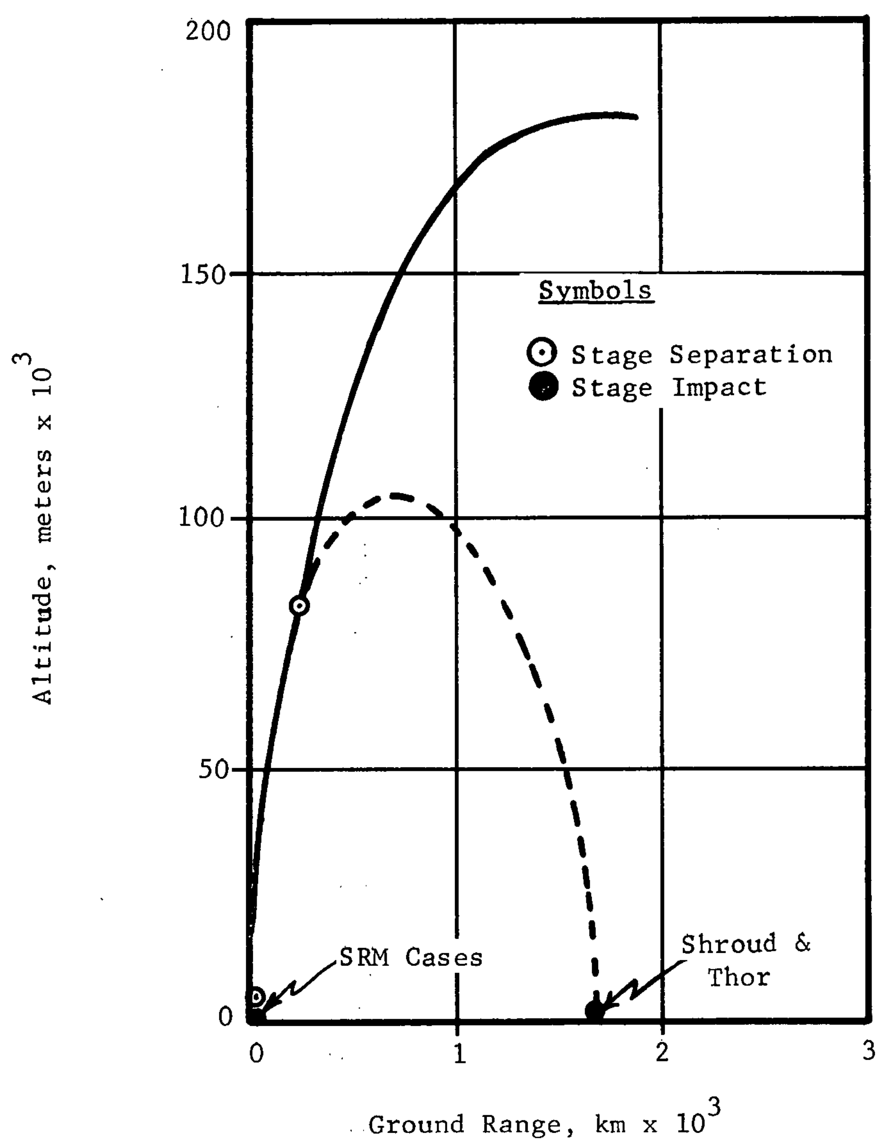

FIGURE B-3. EXAMPLE TRAJECTORY ELEVATION FOR THOR(3 CASTOR)/DELTA(TSE)

Note: To convert to feet, multiply meters by 3.28
To convert to nautical miles, multiply kilometers by 0.54

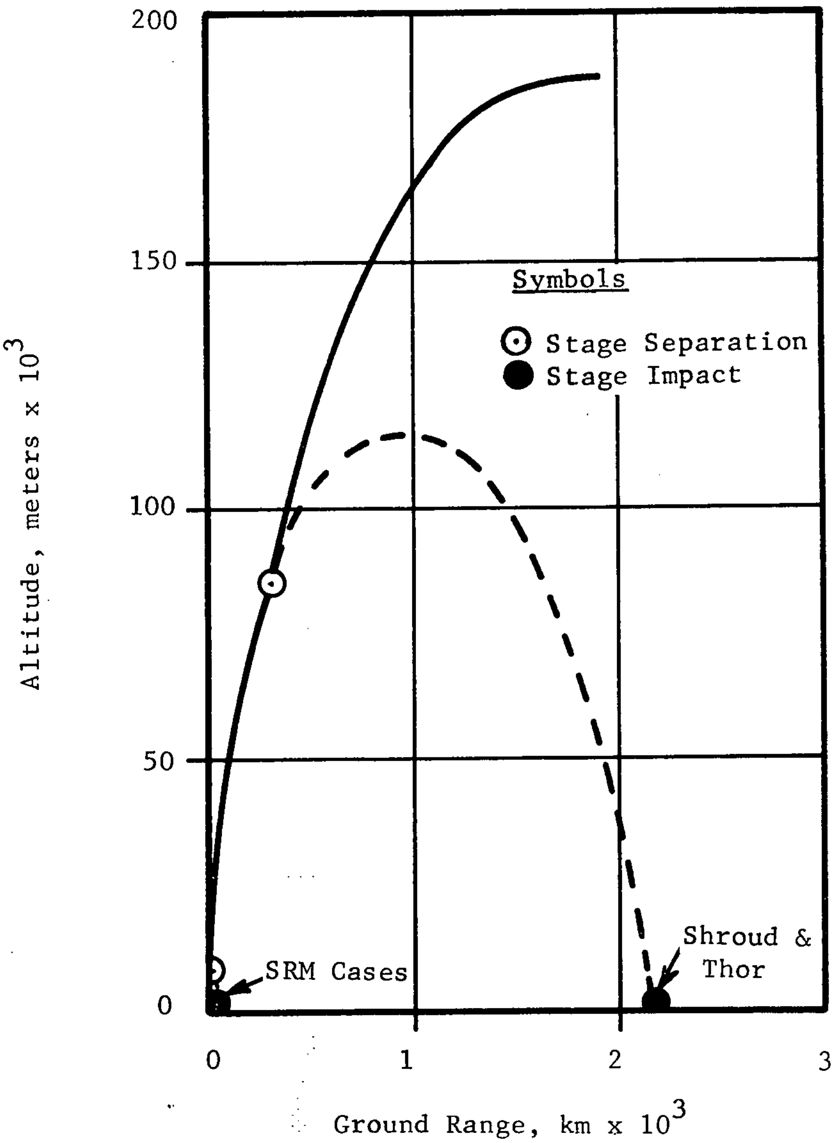

FIGURE B-4. EXAMPLE TRAJECTORY ELEVATION FOR THOR(6 CASTOR)/DELTA(TSE)

Note: To convert to feet, multiply meters by 3.28
To convert to nautical miles, multiply kilometers by 0.54

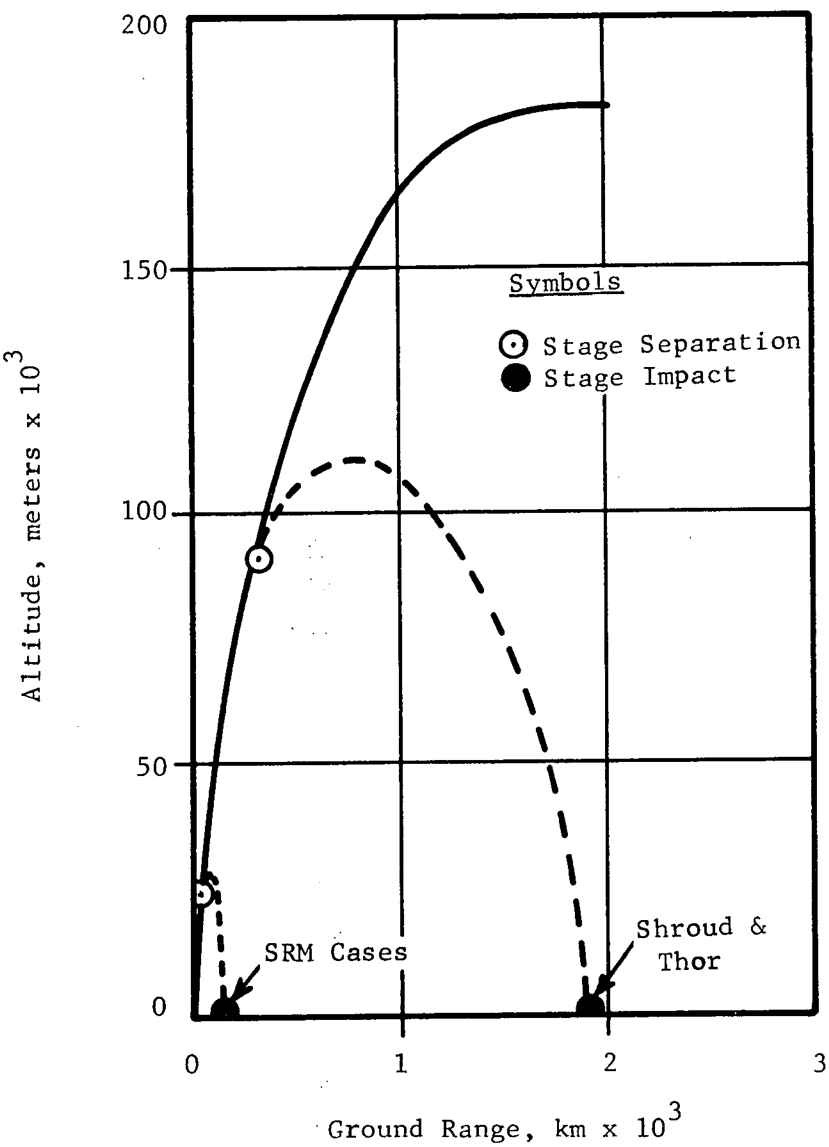

FIGURE B-5. EXAMPLE TRAJECTORY ELEVATION FOR THOR(9 CASTOR)/DELTA(TSE)

Note: To convert to feet, multiply meters by 3.28
To convert to nautical miles, multiply kilometers by 0.54

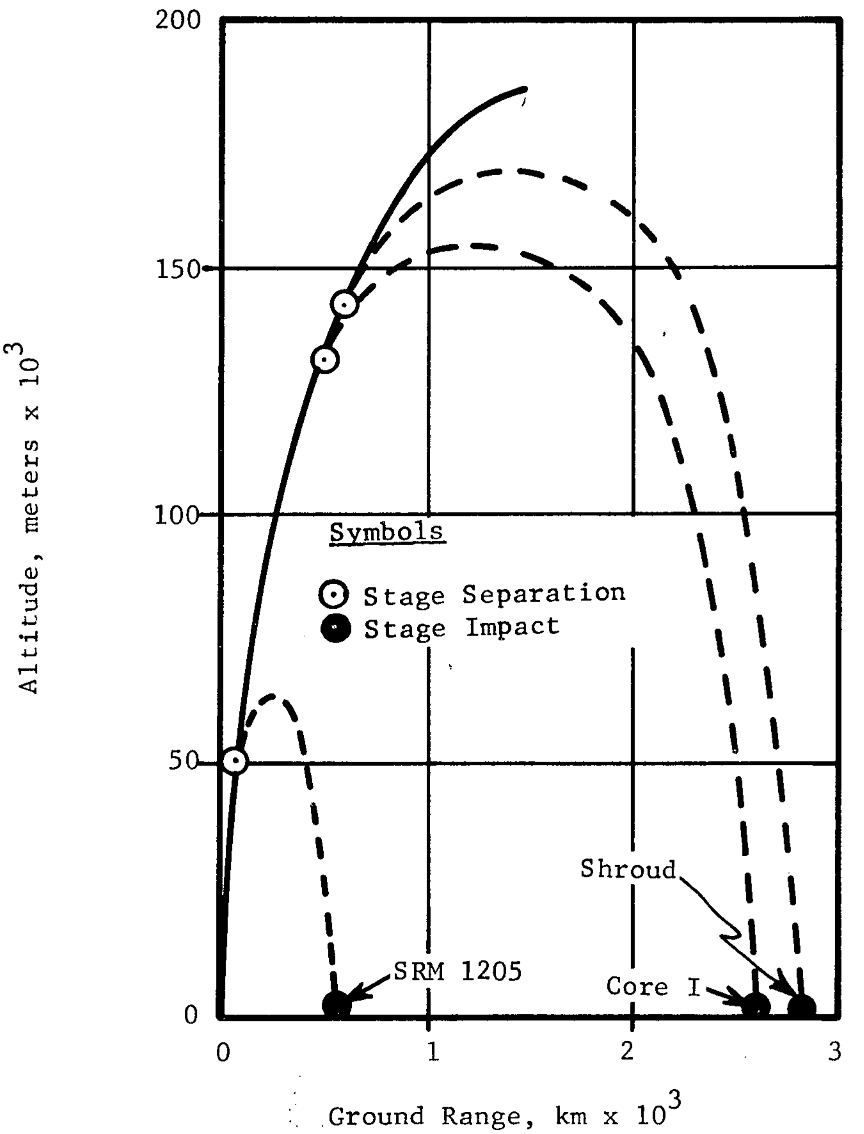

FIGURE B-6. EXAMPLE TRAJECTORY ELEVATION FOR TITAN IIIC

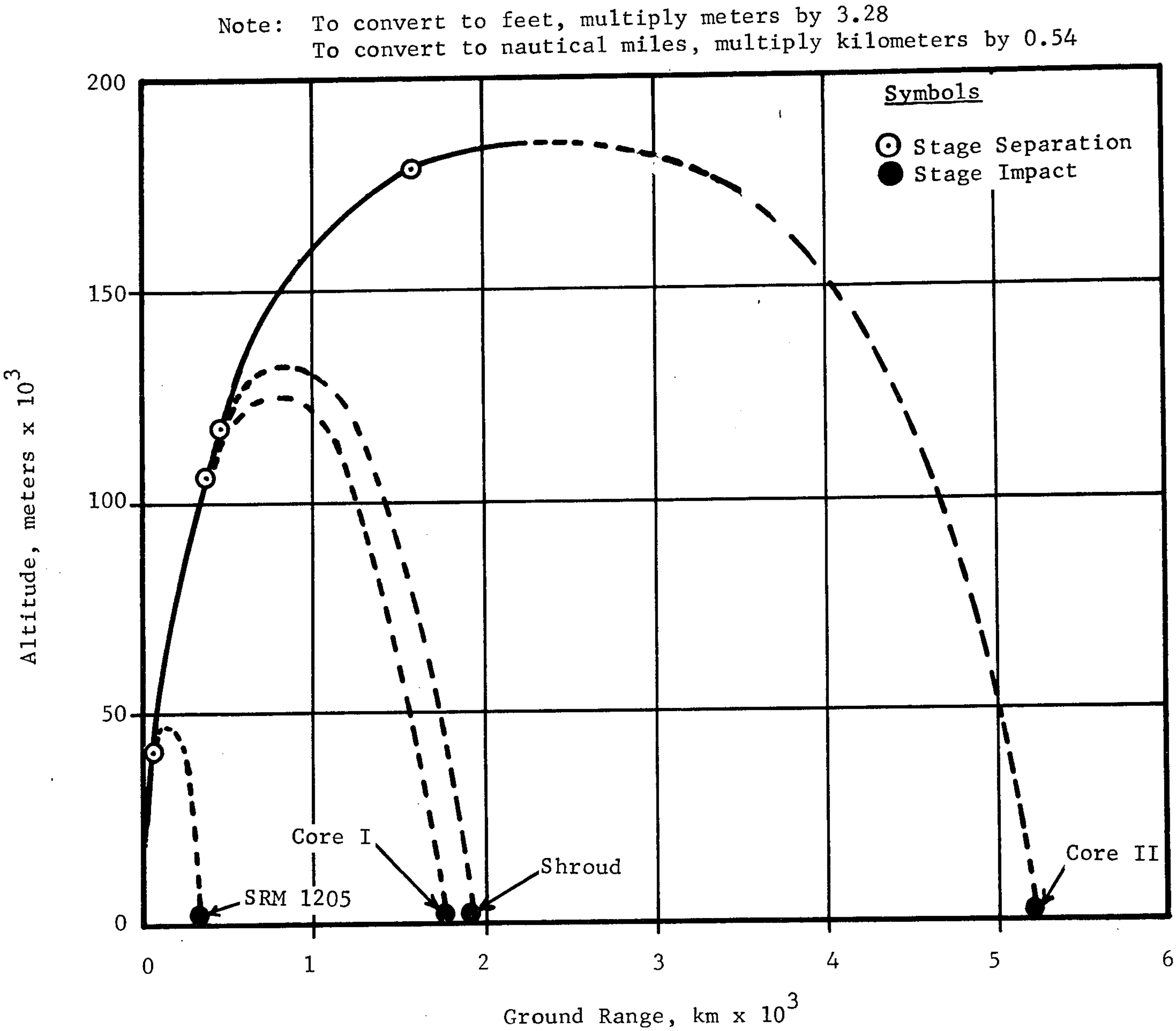

FIGURE B-7. EXAMPLE TRAJECTORY ELEVATION FOR TITAN IIIE/CENTAUR

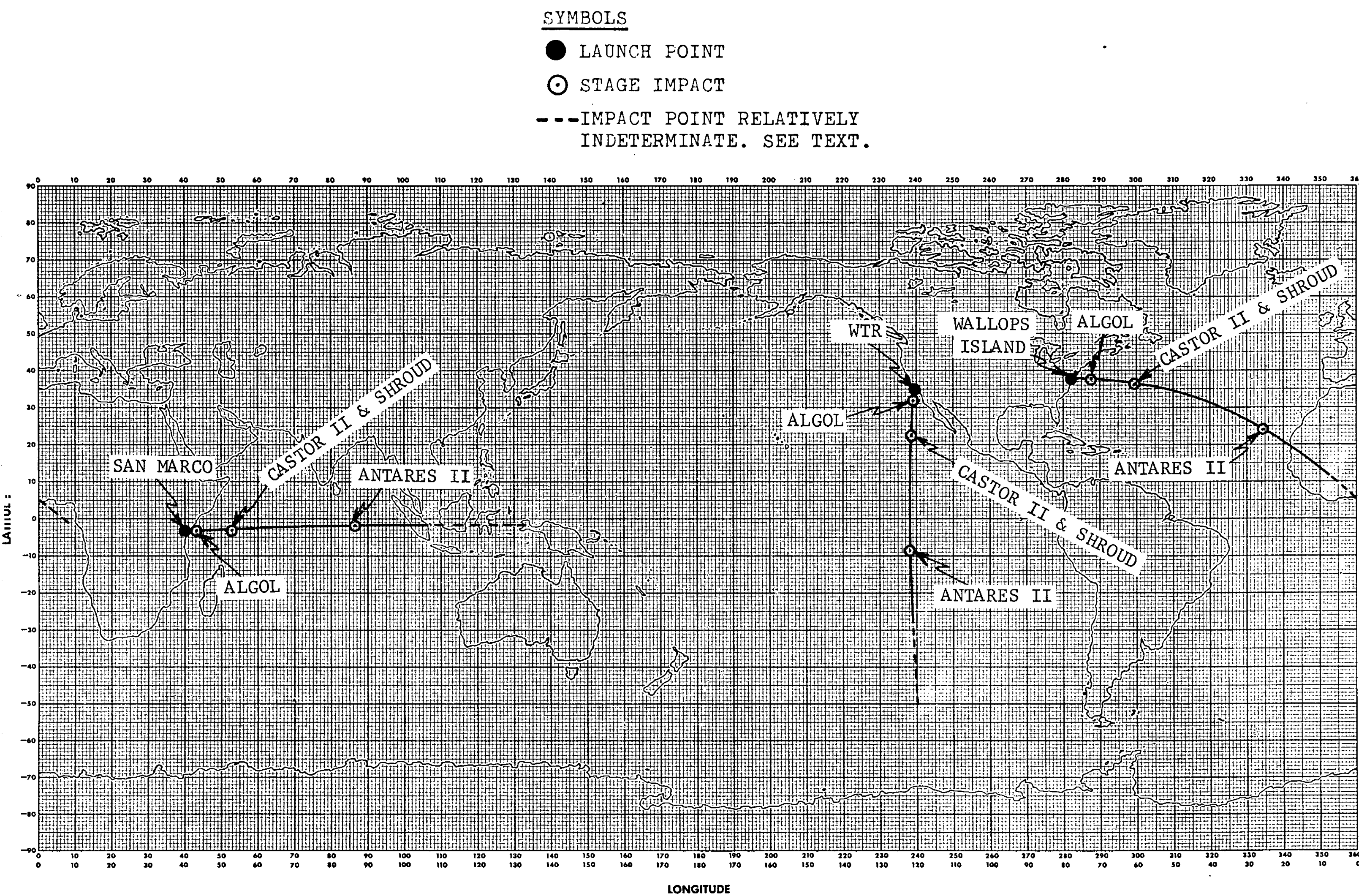

FIGURE B-8. EXAMPLE LOCI OF IMPACT POINTS FOR SCOUT
(LAUNCHES FROM WALLOPS ISLAND, WTR, AND SAN MARCO)

SYMBOLS

● LAUNCH POINT

⊙ STAGE IMPACT

- - -IMPACT POINT RELATIVELY INDETERMINATE. SEE TEXT.

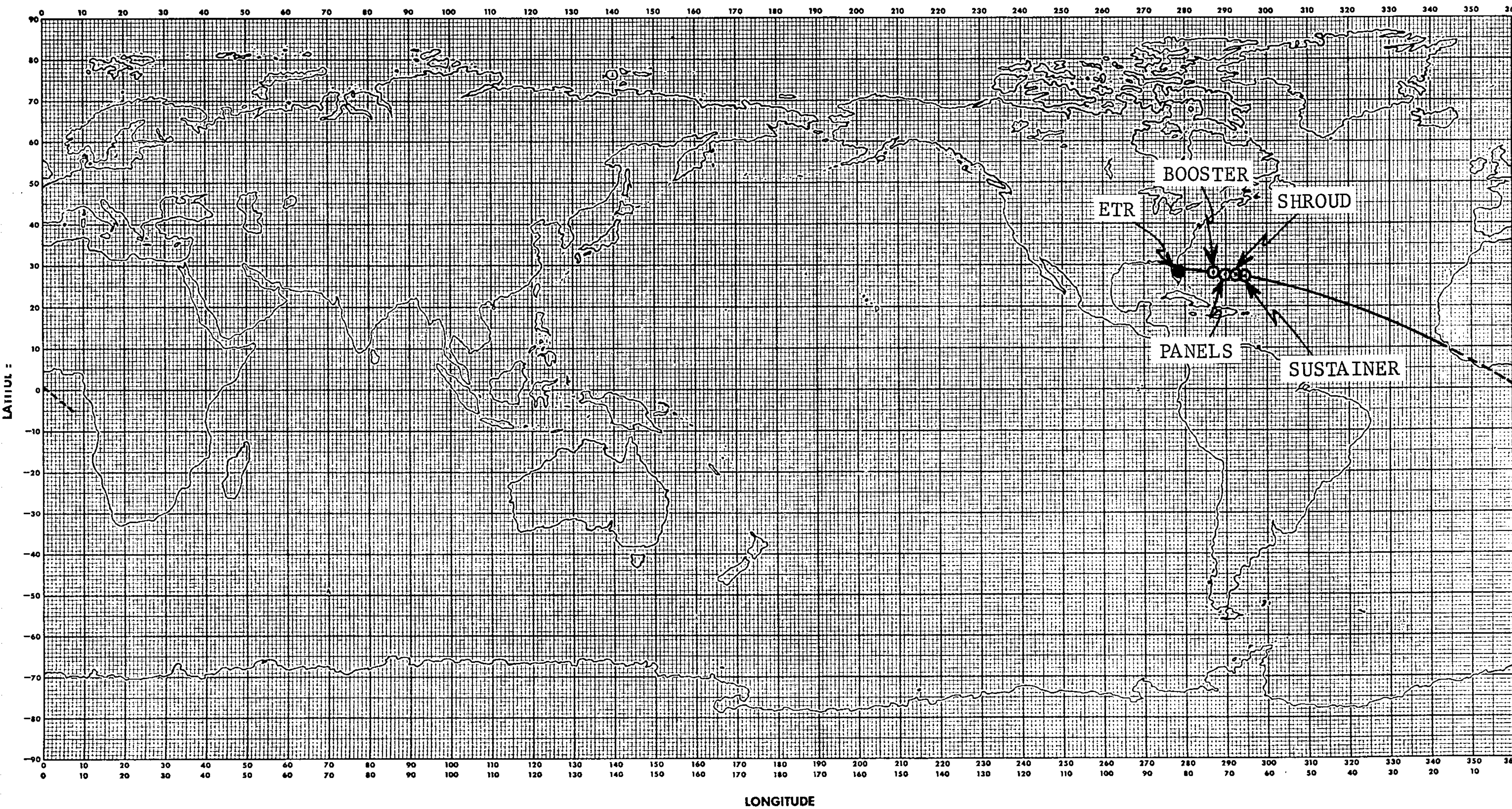

FIGURE B-9. EXAMPLE LOCUS OF IMPACT POINTS FOR SLV3D/CENTAUR (LAUNCH FROM ETR)

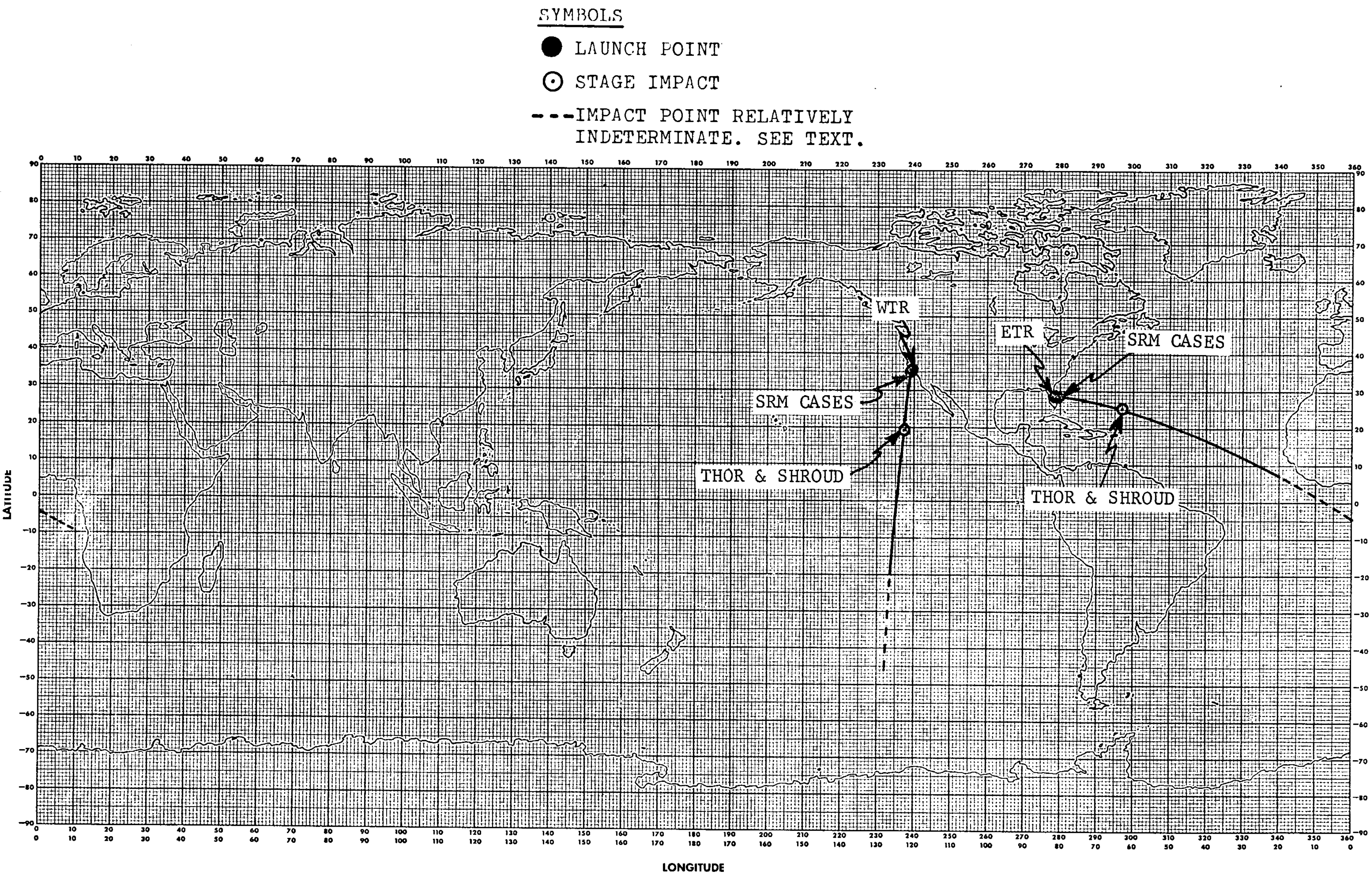

FIGURE B-10. EXAMPLE LOCI OF IMPACT POINTS FOR THOR(3 CASTOR)/DELTA(TSE)
(LAUNCHES FROM WTR AND ETR)

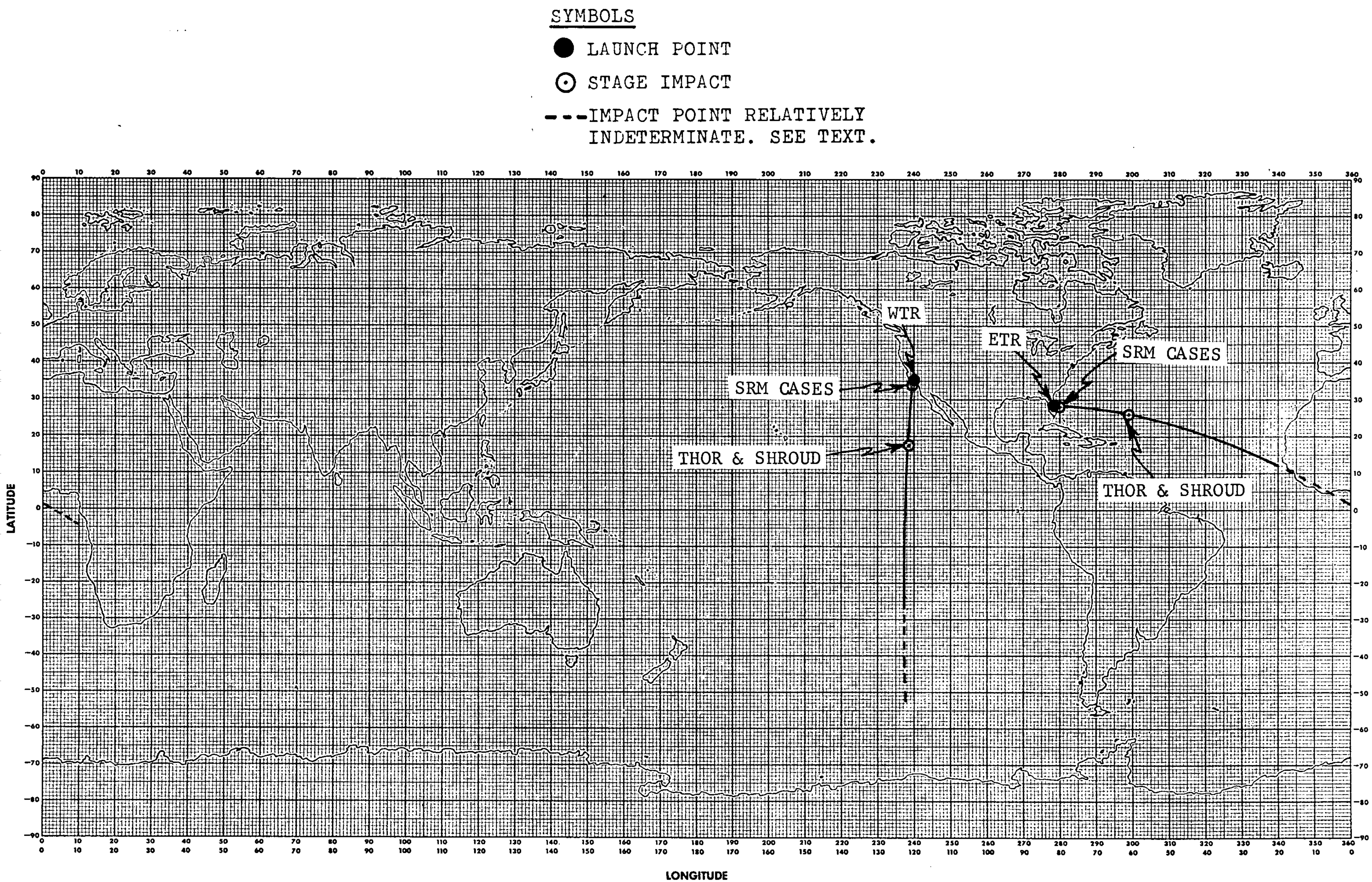

FIGURE B-11. EXAMPLE LOCI OF IMPACT POINTS FOR THOR(6 CASTOR)/DELTA(TSE)
(LAUNCHES FROM WTR AND ETR)

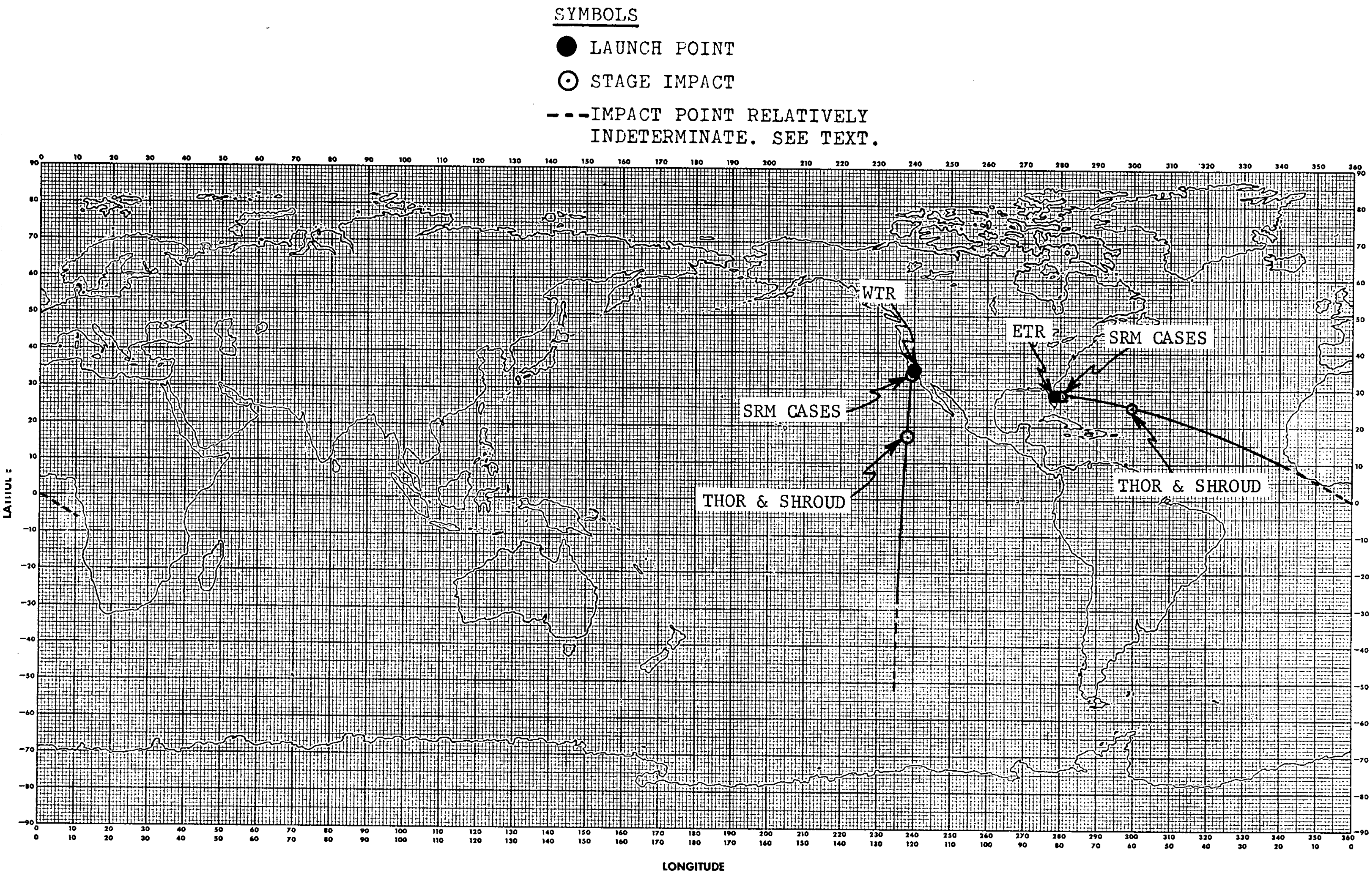

FIGURE B-12. EXAMPLE LOCI OF IMPACT POINTS FOR THOR(9 CASTOR)/DELTA(TSE)
(LAUNCHES FROM WTR AND ETR)

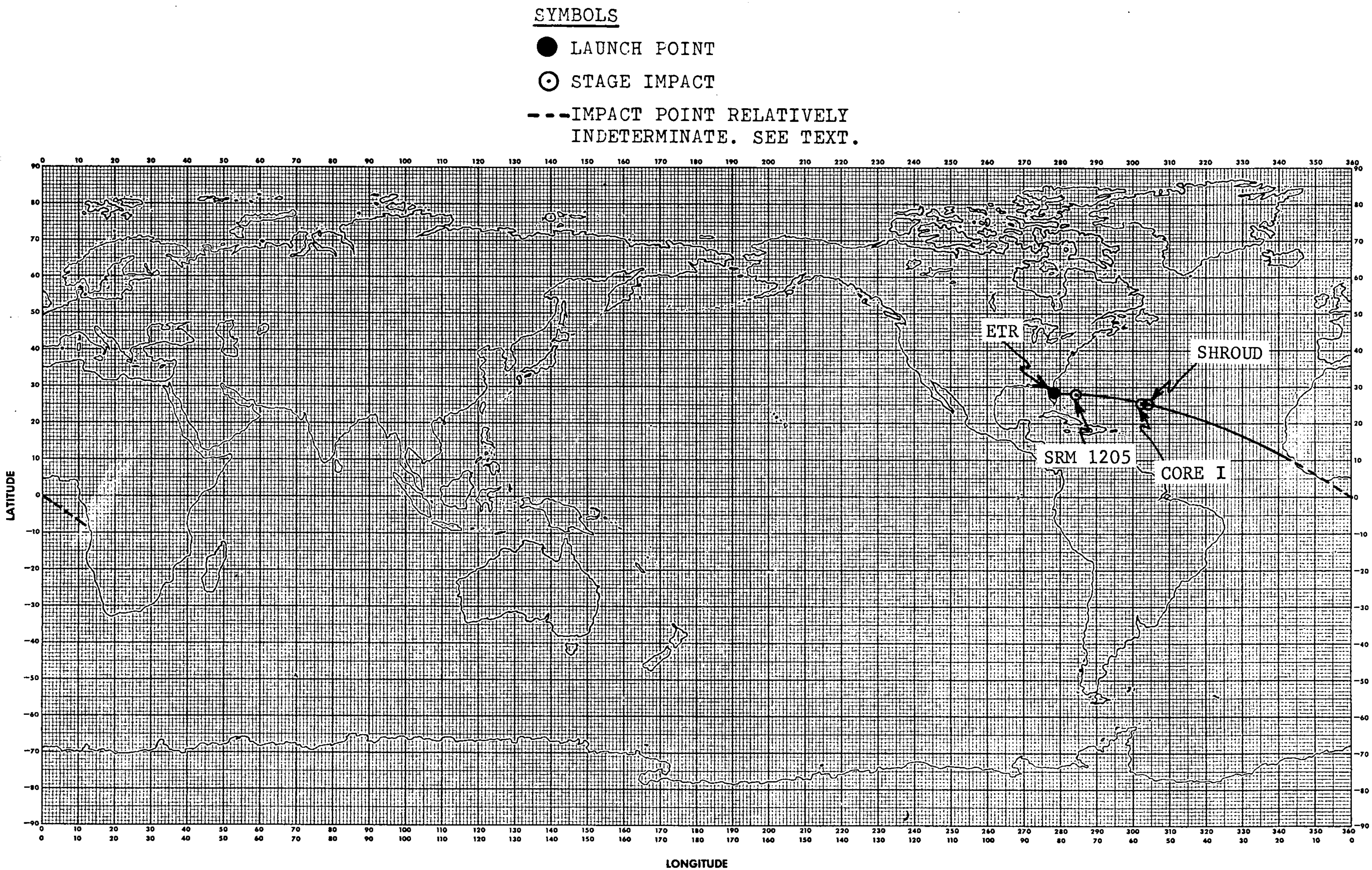

FIGURE B-13. EXAMPLE LOCUS OF IMPACT POINTS FOR TITAN IIIC (LAUNCHES FROM ETR)

APPENDIX C

LAUNCH SITE MAPS AND DISTANCE TABLE

Figures C-1 through C-4 are maps of the four launch sites employed by the NASA OSS Launch Vehicle and Propulsion Programs. For the Kennedy Space Center (ETR) and Vandenberg Air Force Base (WTR), the specific launch pads used by this program are identified. Scout is the only space launch vehicle launched from the facilities at Wallops Island and San Marco.

Table C-1 identifies the minimum distances between the specific launch pads and the press site (where appropriate), the nearest facility boundary, and the nearest community. The press site represents the closest permitted approach of uncontrolled personnel to the launch pad during a launch. It should be noted that, while press representatives and other viewers may be uncontrolled in the sense of medical histories and periodic health examinations, their movements are controlled by the responsible agency and they may be provided with and required to use protective equipment. The nearest facility boundary represents the closest possible approach of completely uncontrolled persons.

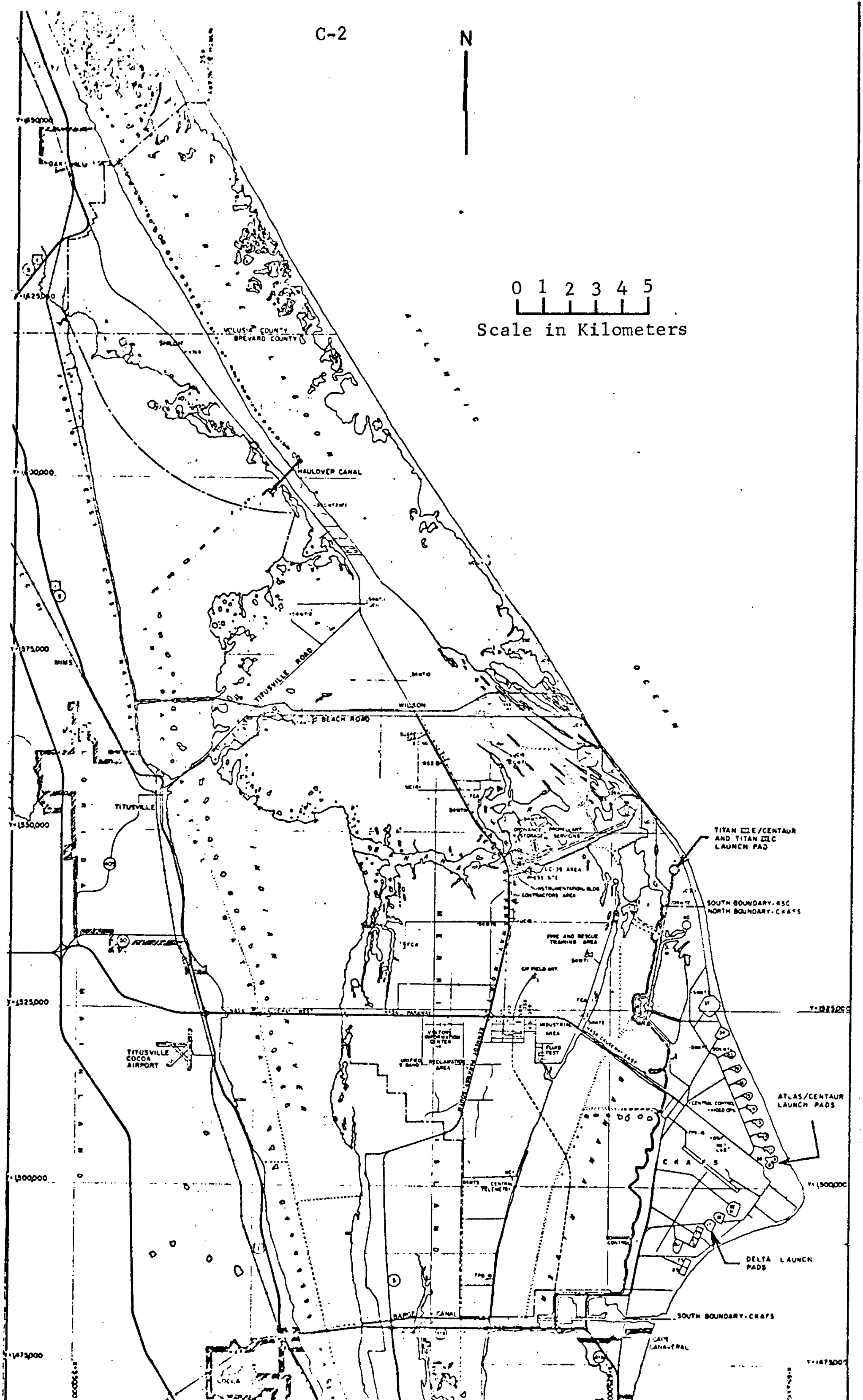

FIGURE C-1. MAP OF KENNEDY SPACE CENTER (ETR) AND SURROUNDINGS

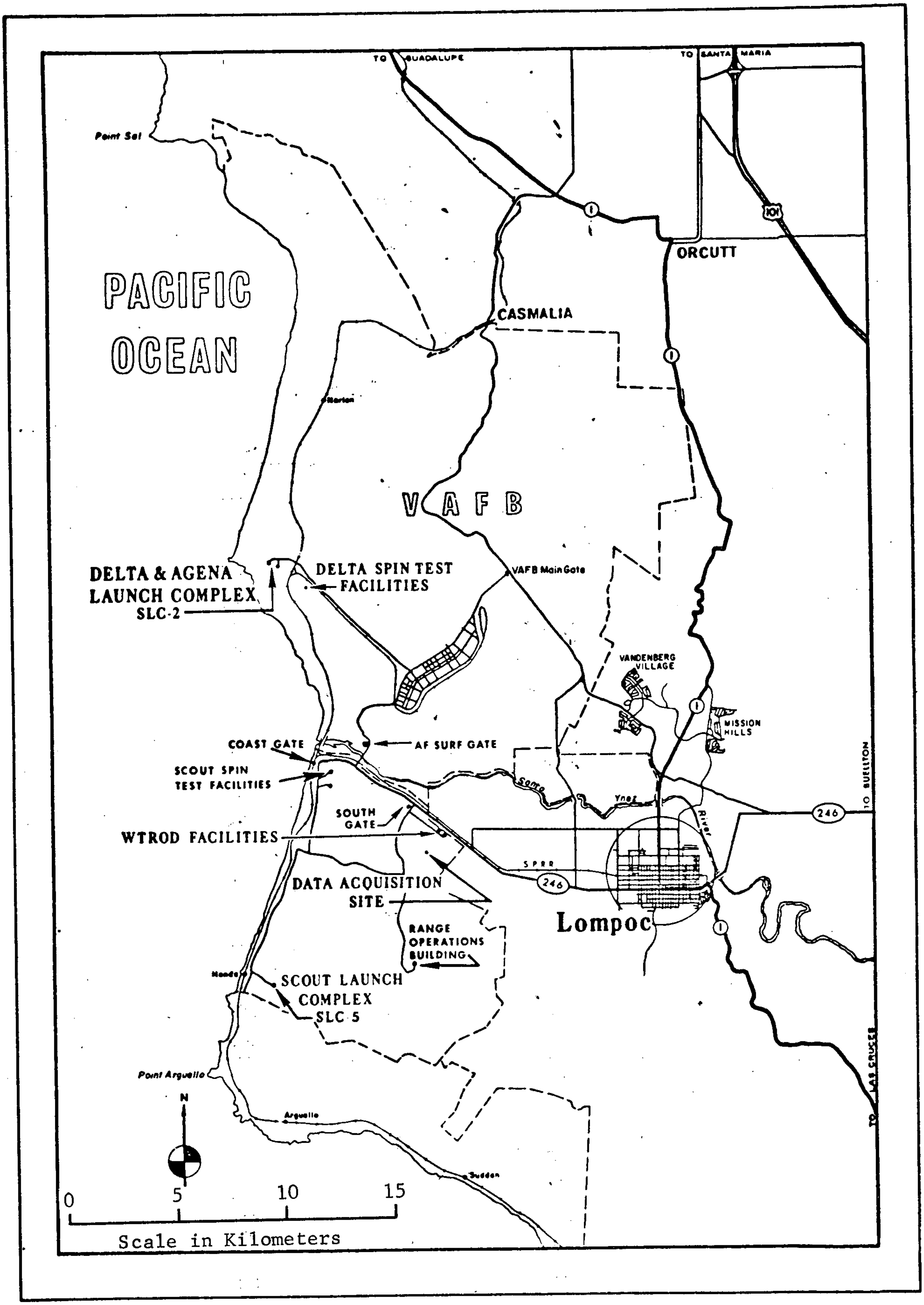

FIGURE C-2. MAP OF VANDENBERG AIR FORCE BASE (WTR) AND SURROUNDINGS

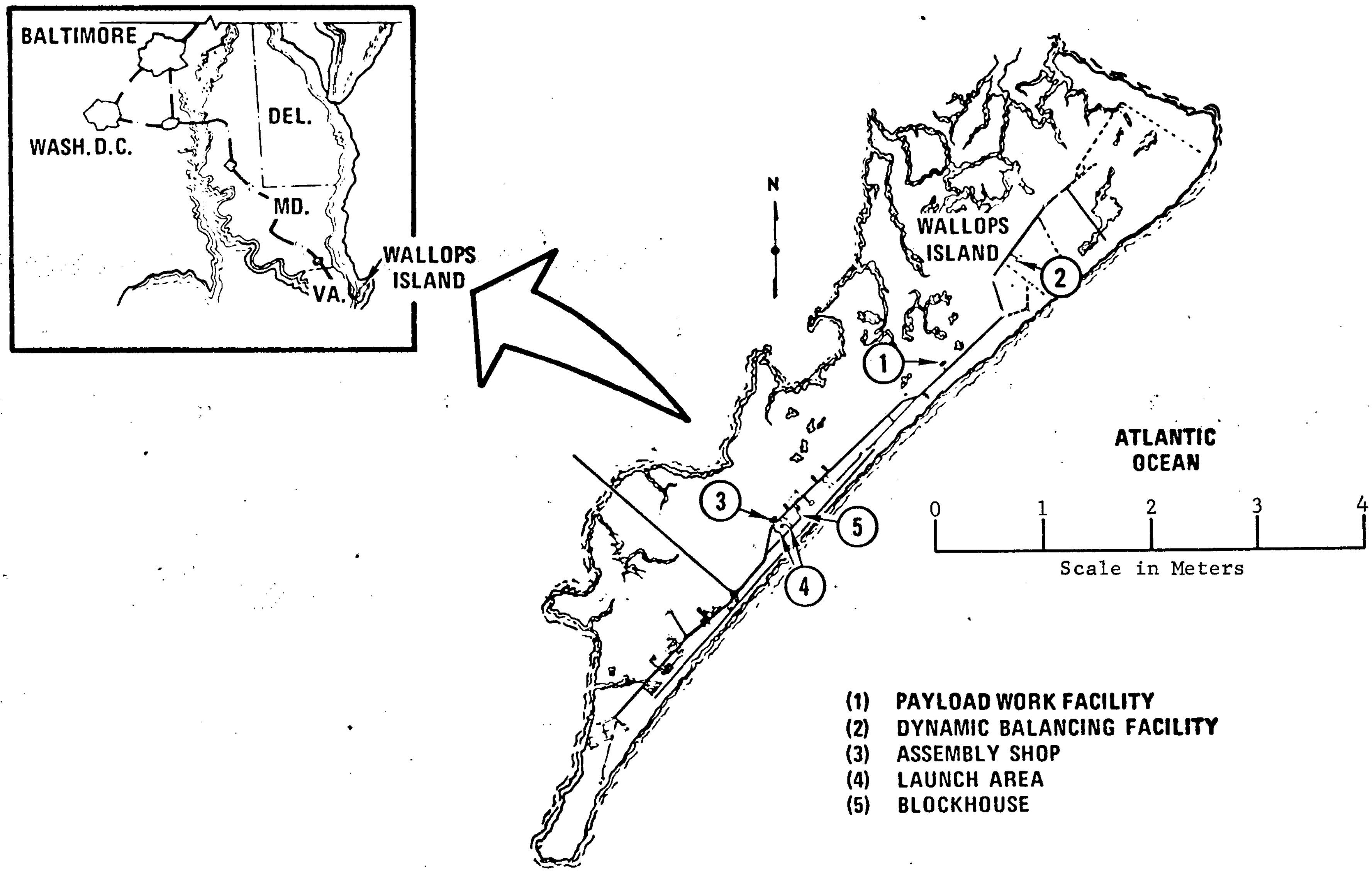

FIGURE C-3. MAP OF WALLOPS ISLAND (SCOUT LAUNCH FACILITY)

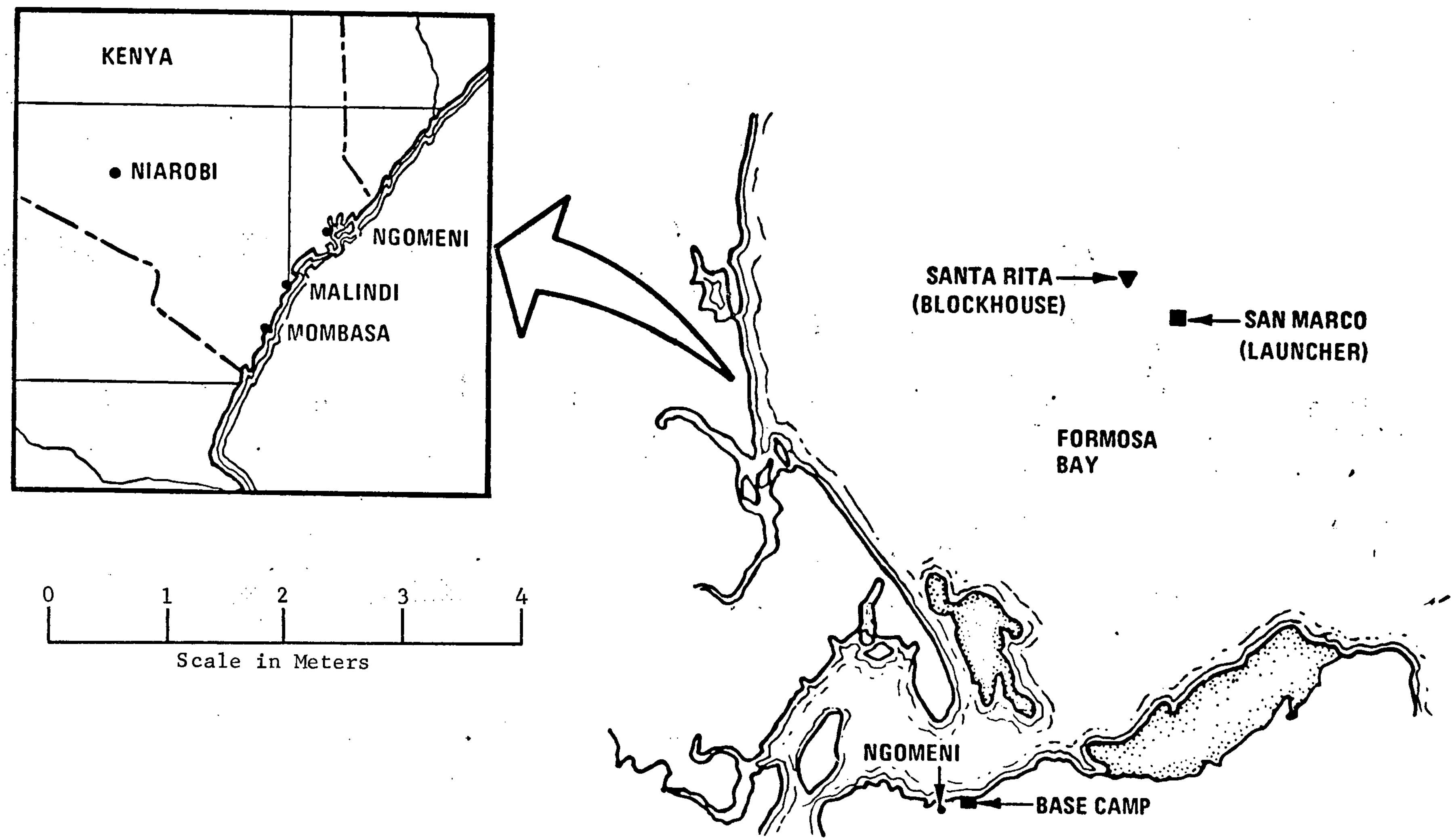

FIGURE C-4. MAP OF SAN MARCO LAUNCH COMPLEX AND SURROUNDINGS. (SCOUT LAUNCH FACILITY)

TABLE C-1. DISTANCES FROM LAUNCH PADS TO POINTS OF POTENTIAL CONCERN

Note: All dimensions are in meters. To convert to feet multiply meters by 3.28.

Vehicle	Press Site	Nearest Boundary	Nearest Community
	ETR		
Titan IIIE/Centaur and Titan IIIC	5,790	13,260	19,810
Atlas/Centaur	4,540	7,930	9,140
Delta	2,710	4,720	5,490
	WTR		
Delta	No Permanent Facilities	12,800	14,170
Scout		7,320	14,480
	Wallops Island		
Scout	(No Permanent Facility)	2,010	8,110
	San Marco		
Scout	(No Permanent Facility)	(Launch Pad is on a platform in Formosa Bay. Distance to nearest shore is 3,320 m.)	4,820